GEORGIA INSTITUTE OF TECHNOLOGY
Engineering Experiment Station
Atlanta, Georgia

QUARTERLY STATUS REPORT NO. 1

Contract Period: 1 December 1962 - 28 February 1963

Contract Number: AF19(628)-2416

Georgia Tech Project No. A-669

Contract Objective: Study of Natural Ultraviolet Backgrounds at High Altitudes

Contract Sponsor: Geophysics Research Directorate
Air Force Cambridge Research Laboratories
Air Force Office of Aerospace Research
United States Air Force
Bedford, Massachusetts

Principal Investigator: Howard D. Edwards

This report is intended only for the internal management uses of the contractor and the Air Force

1. Investigations Being Undertaken

During the quarter, project personnel were engaged in the following activities:

(a) The mechanical system for scanning the spectrometer in elevation was designed and components ordered. Drawings of the upper portion of the bi-axial pointer were received from Mr. A. Goddard of Hi-Altitude Instrument Company. Considerable effort was devoted to making our design compatable with that of Hi-Altitude Instrument.

(b) The scattered light distribution as a function of wavelength was checked in the spectrometer.

(c) A study of the transmission of the spectrometer as a function of wavelength has been initiated.

(d) An auxilliary photomultiplier has been calibrated to be used as a test probe.

A trip was made to Baltimore, Maryland during the week of 21 January 1963 and details of the photomultiplier head and associated components were discussed with representatives of Ray Lee Machine Company and Hruska Radio. Subsequently, a proposal was obtained from Ray Lee Machine Company for providing the necessary components and installation on the basic spectrometer.

A trip was made to Boston on 21 February 1963 and discussions held with Mr. R. Toolin, the project scientist.

2. Plans for Next Period

(a) Obtain components and fabricate spectrometer scanning system.

(b) Check polarization and alignment of present grating and optics (visible) in instrument prior to returning to Ray Lee for installation of ultraviolet photometer head and other components. (These series of checks will serve to establish procedures for alignment and tests which will be used when the U.V. instrument is complete. In addition, they will provide information needed for the analyses of test data taken in the field during October - December 1962.)

3. Scientific Reports Published - Study of Natural Ultraviolet Backgrounds at High Altitude by H. D. Edwards, E. Rhodes, D. Kurts. Final Report AF19(604)8840, December 1962. (Covers first year's activities of the present effort)

4. Papers Presented - None.

5. Visitors - None.

6. Travel - Baltimore, Maryland (week of 21 January 1963)
   Boston, Massachusetts (21 February 1963)

7. Personnel Change - Mr. Ellis Hodgdon, a graduate student in the Physics Department, joined the project on 28 January 1963.

8. Important Property Acquired - None.

9. Fiscal Information - The estimated unencumbered balance remaining on 28 February 1963 was approximately $32,300.

Submitted by:

Howard D. Edwards
Project Director

GEORGIA INSTITUTE OF TECHNOLOGY
Engineering Experiment Station
Atlanta, Georgia

QUARTERLY STATUS REPORT NO. 2

Contract Period: 1 March 1963 - 31 May 1963

Contract Number: AF19(628)-2416
Georgia Tech Project No. A-669

Contract Objective: Study of Natural Ultraviolet Backgrounds at High Altitudes

Contract Sponsor: Air Force Cambridge Research Laboratories
Office of Aerospace Research
United States Air Force
Bedford, Massachusetts

Principal Investigator: Howard D. Edwards

This report is intended only for the internal management uses of the contractor and the Air Force

1. Investigations Being Undertaken

During the quarter, project personnel were engaged in the following activities.

(a) Work has continued on the mechanical system for scanning the photometer and several important components are now complete. Additional baffling was found to be necessary and is underway. Delivery of certain key items, such as motors, has become a problem.

(b) The complete photometer head was ordered and delivered. Tests have shown problems in this unit and steps are being taken to correct them. A separate phototube system was found necessary to protect the primary photomultipliers if accidentally pointed at the sun. Work is underway on this unit.

(c) Polarization studies associated with the spectrometer measurements have developed into a major problem. A quarter-wave plate and polaroid for the U.V. region have been received and are in the process of being installed.

(d) The anticipated range of light intensities has again been reviewed to insure maximum "on-scale" readings during the flight.

(e) Data analysis by computer techniques is continuing to play a dominant role in planning the instrumentation. Contact is continuing with the Tele-Computing group at Holloman Air Force Base and the digital and analog computer groups at Georgia Tech.

2. Plans for Next Period

   (a) A major effort will be made to assemble the complete unit for laboratory tests. Undoubtedly, unforseen problems will arise when the tests are made.

3. Scientific Reports Published - None.

4. Papers Presented - None.

5. Visitors - None.

6. Travel - None.

7. Personnel Changes - None.

8. Important Property Acquired - Some rather expensive units, such as the $6,000 photometer head, have been acquired but all are components of the spectrometer.

9. Fiscal Information - The estimated unencumbered balance remaining on 31 May 1963 was approximately $11,500.

Submitted by:

H. D. Edwards
Project Director

A-669

GEORGIA INSTITUTE OF TECHNOLOGY
Engineering Experiment Station
Atlanta, Georgia

QUARTERLY STATUS REPORT NO. 3

Contract Period: 1 June 1963 - 31 August 1963

Contract Number: AF 19(628)-2416

Georgia Tech Project No. A-669

Contract Objective: Study of Natural Ultraviolet Backgrounds at High Altitudes

Contract Sponsor: Air Force Cambridge Research Laboratories
Office of Aerospace Research
United States Air Force
Bedford, Massachusetts

Principal Investigator: Howard D. Edwards

This report is intended only for the internal management uses of the contractor and the Air Force.

1. Investigations Being Undertaken

During the quarter, project personnel were engaged in the following activities.

(a) Mechanical The quarter-wave plate mount was completed and due to the difficulty in obtaining the flight drive motor a substitute was mounted for lab testing. The scanning system has been essentially completed and mated with the base and servo units from High Altitude Instrument Company. The interior baffling was completed and the design for the exterior baffling begun.

All mechanical components were subjected to a vacuum of 10^{-3} mm of Hg to remove volatile shop oils which might deposit on the grating under flight conditions.

(b) Electronics Tests were made on the amplifiers in the photometer head to determine: (1) frequency response, (2) sharpness of break in the diode sensitivity switch, and (3) range of intensities which would give an output between zero and five volts. Since frequency response dropped off sharply at ten cycles per second, modifications were made to increase this to 100 cps.

A solar monitor was designed and fabricated. This device will monitor solar intensity in the 3000 Å to 4000 Å region and will also provide data on times that the pointing control loses the sun.

(c) Optics The optics including the U.V. grating and polacoat analyzer were assembled, aligned and focussed.

(d) Calibration Toward the latter part of the quarter, the instrument had reached a stage in its construction which permitted it to be calibrated in part. A procedure has been developed and applied which resulted in calibration of part of the instrument. Refinements will continue to be made in this procedure which should result in a more accurate calibration.

(e) Data Analysis A general plan for the complete reduction of data has been made, and a computer program has been developed and checked which produces the results from the input data in a convenient form for interpretation.

2. Plans for Next Period

(a) Continue laboratory tests, and design and fabrication of components not yet complete.

(b) Activities will be limited due to a shortage of funds.

3. Scientific Reports Published - None.

4. Papers Presented - None.

5. Visitors - None.

6. Travel - None.

7. Personnel Changes - None.

8. Important Property Acquired - Some critical elements of the balloon pointing control were purchased at a cost of $7,000.00.

9. Fiscal Information - The estimated unencumbered balance remaining on 31 August 1963 was approximately $2,000.00.

Submitted by:

H. D. Edwards
Project Director

GEORGIA INSTITUTE OF TECHNOLOGY
Engineering Experiment Station
Atlanta, Georgia

QUARTERLY STATUS REPORT NO. 4

Contract Period: 1 September 1963 - 30 November 1963

Contract Number: AF 19(628)-2416

Georgia Tech Project No. A-669

Contract Objective: Study of Natural Ultraviolet Backgrounds at High Altitudes

Contract Sponsor: Air Force Cambridge Research Laboratories
Office of Aerospace Research
United States Air Force
Bedford, Massachusetts

Principal Investigator: Howard D. Edwards

This report is intended only for the internal management uses of the contractor and the Air Force

1. Investigations Being Undertaken

During the quarter project personnel were engaged in the following activities:

(a) Mechanical - Flight drive motor and reference generator were received and have been mounted. Work has been started on the shutter housing and shutter.

(b) Electronics - A replacement power supply has been ordered with delivery expected in January.

(c) Optics - The assembly of the optics is essentially complete.

(d) Calibration and Data Analysis - These procedures are being refined and written up.

2. Plans for Next Period

Mount instrument in the pointing control yoke and run a complete calibration and data analysis check.

3. Scientific Reports Published - None.

4. Papers Presented - None.

5. Visitors - None.

6. Travel - None.

7. Personnel Changes - None.

8. Important Property Acquired - None.

9. Fiscal Information - The estimated unencumbered balance remaining on 30 November 1963 was $300.

Submitted by:

H. D. Edwards
Project Director

GEORGIA INSTITUTE OF TECHNOLOGY
Engineering Experiment Station
Atlanta, Georgia

QUARTERLY STATUS REPORT NO. 5

Contract Period: 1 December 1963 - 29 February 1964

Contract Number: AF 19(628)-2416

Georgia Tech Project No. A-669

Contract Objective: Study of Natural Ultraviolet Backgrounds at High Altitudes

Contract Sponsor: Air Force Cambridge Research Laboratories
Office of Aerospace Research
United States Air Force
Bedford, Massachusetts

Principal Investigator: Howard D. Edwards

This report is intended only for the internal management uses of the contractor and the Air Force

1. Investigations Being Undertaken

During the quarter project personnel were engaged in the following activities:

(a) Mechanical - Construction of the shutter housing and shutter were completed and mounted on the quarter-wave plate assembly. Final construction was performed, and the spectrometer has been mounted on the yoke which will be mated with the pointing control supplied by High Altitude Instrument Company.

(b) Electronics - Final wiring of the instrument was performed. The construction of the shutter actuator was completed, tested, and mounted. The 2-hour "turn-on" timer was received, and mounted, and wired. Batteries for the photomultiplier amplifiers and high voltage supply were obtained, charged, and mounted on the yoke. Other miscellaneous details were performed to essentially complete the electronic portion of the instrument.

(c) Optics - The phase plate for the 2000 to 3200 Å region was received and mounted in its appropriate holder. The optical work is complete except for a possible general cleaning prior to flight.

(d) Calibration and Data Analysis - One phase of the calibration has been accomplished, and the procedures for both calibration and data analysis are being prepared for a publication.

2. Plans for Next Period

It is hoped that the mechanical and electronic portion of the spectrometer will be complete within a month. The instrument will be mated with the bi-axial pointing control at Golden, Colorado. After the return from

Colorado, calibration and system checks will be initiated. With luck and sufficient funds the instrument should be ready for a summer launch.

3. Scientific Reports Published - None.

4. Papers Presented - None.

5. Visitors - Dr. E. C. Zipf, from the Joint Institute for Laboratory Astrophysics of the University of Colorado, visited the project on February 17 and 18, 1964.

6. Travel - None.

7. Personnel Changes - None.

8. Important Property Acquired - None.

9. Fiscal Information - The estimated unencumbered balance remaining on 29 February 1964 was $23,000.

Submitted by:

H. D. Edwards
Principal Investigator

GEORGIA INSTITUTE OF TECHNOLOGY
Engineering Experiment Station
Atlanta, Georgia

QUARTERLY STATUS REPORT NO. 6

Contract Period: 1 March 1964 - 31 May 1964

Contract Number: AF 19(628)-2416

Georgia Tech Project No.: A-669

Contract Objective: Study of Natural Ultraviolet Backgrounds at High Altitudes

Contract Sponsor: Air Force Cambridge Research Laboratories
Office of Aerospace Research
United States Air Force
Bedford, Massachusetts

Principal Investigator: Howard D. Edwards

This report is intended only for the internal management uses of the contractor and the Air Force

1. Investigations Being Undertaken

During the quarter project personnel were engaged in the following activities:

(a) Mechanical The major mechanical work is now complete. The instrument was shipped to Hi Altitude Instrument Company, Golden, Colorado, for physical mating with the bi-axial pointing control and associated tests and adjustments. Construction of the gondola is underway at Hi Altitude Instrument Company.

(b) Electronics The power requirements of the instrument were determined. Two battery packs are needed: one, at 28 volts, for the spectrometer and pointing control; the other at 6 volts, for the telemetry and commutator. The commutators were received from AFCRL and preliminary work on their wiring, mounting, and evaluation tests has been completed. Minor electrical changes were made while the instrument was being mated with the pointing control.

(c) Calibration and Data Analysis The calibration procedures have been refined slightly, and preparations have been made or initiated for the calibration of the spectrometer and associated equipment upon its return from Hi Altitude Instrument Company.

(d) Pointing Control and Gondola The solar monitor, which measures changes in the sun's intensity, was mounted on the "eye" beam of the pointing control. The fine and coarse error sensors were mounted on the yoke assembly, and the yoke assembly was mounted on the gondola spider with the necessary electrical connections passing through a set of slip rings. Tests were made to measure the effect of the elevation scanning action of the spectrometer on the stability of the pointing control, and it was found to be negligible. Final assembly and tests are being conducted at Golden, Colorado during the latter half of the quarter.

2. Plans for Next Period

Upon receipt of the instrument from Hi Altitude Instrument Company, tests will be made in open sunlight. Instrument calibration is the major problem remaining and it is hoped that this will be complete by the middle of the quarter. The instrument will then be mated with the telemetry in Boston and final arrangements for the flight made.

3. Scientific Reports Published - None.

4. Papers Presented - None.

5. Visitors - None.

6. Travel - Mr. E. B. Hodgdon traveled to Golden, Colorado to facilitate mating of the spectrometer and pointing control.

7. Personnel Changes - None.

8. Important Property Acquired - None.

9. Fiscal Information - The estimated unencumbered balance remaining on 31 May 1964 was $16,000.

Submitted by:

H. D. Edwards
Principal Investigator

GEORGIA INSTITUTE OF TECHNOLOGY
Engineering Experiment Station
Atlanta, Georgia

QUARTERLY STATUS REPORT NO. 7

Contract Period: 1 June 1964 - 31 August 1964

Contract Number: AF 19(628)-2416
Georgia Tech Project No.: A-669

Contract Objective: Study of Natural Ultraviolet Backgrounds at High Altitudes

Contract Sponsor: Air Force Cambridge Research Laboratories
Office of Aerospace Research
United States Air Force
Bedford, Massachusetts

Principal Investigator: Howard D. Edwards

This report is intended only for the internal management uses of the contractor and the Air Force

1. Investigations Being Undertaken

During the quarter project personnel were engaged in the following activities:

(a) Telemetry - The spectrometer was mated with the telemetry package in Boston, Massachusetts, at Northeastern University during the earlier portion of the quarter. The transmitter caused interference with the pointing control, and this defect was later corrected in Atlanta. Trouble with one subcarrier oscillator forced the changing of one telemetry input from -2.5 to +2.5 volts to 0 to 5 volts. The received signal looked good, and no added noise or interference was noted.

(b) Mechanical - A 16 mm gun camera and associated intervalometer were mounted so as to photograph shadow sticks mounted on the eye block of the pointing control. Included in the field of view of the camera was a portion of the spectrometer housing and the "wye" spreader above the gondola.

(c) Calibration - The spectrometer was calibrated and tested with different forms of polarized light. The sensitivity of both PM tubes was established from calculations based on the PM tube spectral response curves and Stakutis' previous work.

(d) Pre-Flight - At Holloman Air Force Base, certain modifications had to be made. The utilization of a let-down reel prevented the placement of the AFCRL flight control package on the gondola, so batteries and dead ballast were shifted to rebalance the gondola. Crush pads, ballast hoppers, impact switches, and a method of disabling the TM package had to be added. The instrument was again calibrated just prior to flight.

(e) Flight - The balloon was launched at 0741 MST on 26 August 1964. Premature failure of the electronics batteries caused loss of the PM tube signals at 0752 and abortion of the flight; cutdown was at 1145. Impact was severe and caused extensive damage to the spectrometer yoke. The trip from the impact zone to Holloman AFB was rough and dusty and necessitated the replacement of all bearings in the spectrometer.

(f) Post-Flight - Investigation was begun to determine the cause of the battery failure. It was found that a component failure in one of the PM tube amplifiers caused excessive drain on the battery pack. Plans are being formulated to correct and improve the instrument.

2. Plans for Next Period

Studies of the data obtained will be analyzed and used to improve the present design of the spectrometer. The instrument will be taken apart, cleaned, bearing replaced, and reassembled. Work on two papers will continue.

3. Scientific Reports Published - None.

4. Papers Presented - None.

5. Visitors - None.

6. Travel - (1) H. D. Edwards, E. B. Hodgdon, L. Willard and T. Reed traveled to Holloman Air Force Base, New Mexico for flight of the instrument 15 - 30 August 1964. (2) E. B. Hodgdon traveled to Boston, Massachusetts for telemetering check on 7 - 10 July 1964.

7. Personnel Changes - Dr. C. D. Cooper devoted three weeks time to the project during July-August in reviewing and improving the calibration techniques.

8. Important Property Acquired - None.

9. Fiscal Information - The estimated unencumbered balance remaining on 31 August 1964 was $5,200.

Submitted by:

H. D. Edwards
Principal Investigator

A-669

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GEORGIA INSTITUTE OF TECHNOLOGY
Engineering Experiment Station
Atlanta, Georgia

QUARTERLY STATUS REPORT NO. 8

Contract Period: 1 September 1964 - 30 November 1964

Contract Number: AF 19(628)-2416
Georgia Tech Project No.: A-669

Contract Objective: Study of Natural Ultraviolet Backgrounds at High Altitudes

Contract Sponsor: Air Force Cambridge Research Laboratories
Office of Aerospace Research
United States Air Force
Bedford, Massachusetts

Principal Investigator: Howard D. Edwards

This report is intended only for the internal management uses of the contractor and the Air Force

[redacted]

1. Investigations Being Undertaken

During the quarter project personnel were engaged in the following activities:

(a) Survey of damage - It appears that the spectrometer yoke acted as the shock mount for the spectrometer by breaking at the bends on impact, while the gondola remained intact except for one slightly bent battery bracket. The pointing control drive mechanisms including the hysteresis clutches remained in good condition and relatively free from dust, and the pointing control amplifiers were working properly when on the ground. The detector head, including the photomultiplier tubes, remained intact, as did the other electronic components.

(b) Photomultiplier Tubes - Only preliminary planning has been done on the improvements to the PM tube amplifiers which are necessary for reliable operation. Calculations are being made as to the equilibrium temperature of the detector head at 150,000 feet, and pending the results of these calculations, the two PM tube amplifiers may be enclosed in a temperature controlled box and flown without serious modification to the circuit design.

(c) Pointing Control - Since the pointing control failed during ascent, a complete redesign of the pointing control amplifiers was deemed necessary and has been undertaken. This redesign includes (1) optimization of the load on the silicon solar cell error sensors, (2) incorporation of temperature stabilization in the input and output circuits, and (3) addition of inverse feedback. The basic mechanical design, however, of the pointing control will be maintained. A test panel was constructed for testing the pointing control under environmental conditions.

(d) Mechanical - The spectrometer yoke has been repaired and strengthened over the previous design, and a pressurized battery box is being fabricated to contain the telemetry and detector head batteries. A modification of the quarter-wave plate drive mechanism eliminated a slight ambiguity in the data analysis which had been previously handled by the computer program. A potentiometer has been mounted on the slip ring assembly so that the relative position between the gondola and the spectrometer will be known. Spare components of critical items such as motors, generators, batteries, and DC to DC converter have been ordered and delivery is expected in the near future. Design of adequate shock mounting is continuing.

(e) Calibration - An improved method of calibration which eliminates much of the trouble of the previous method has been developed and checked theoretically. A mount, which contains some polarizing optics, to accomplish this calibration has been designed and is being fabricated. This method, after some preliminary laboratory work, will permit the calibration of the entire spectrometer-polarimeter in one step.

(f) Optics - The grating and mirror have been cleaned and replaced in the spectrometer. The quarter-wave plates have been cleaned, but have not been replaced in their mount pending the anodizing of the new mounting block.

(g) Data analysis - The commutator strip charts and the digital tapes have been received from Telecomputing Services, Inc. Data reduction on these records is being performed and improvements are constantly being made in the method of handling this large volume of data. During the August flight temperature in the optics reached a minimum of approximately

$-28^{\circ}C$ while the temperature in the detector head and pointing control were slightly above this figure. The pointing control started working again at float altitude, approximately 10 minutes before cutdown.

2. Plans for Next Period

Redesign of the pointing control amplifiers should be completed and a suitable electronics package developed for the pointing control. Environmental tests on this and other components will be performed before integrating into the spectrometer. Mechanical reconstruction and calibration of the spectrometer should be completed. It is hoped that a flight can be made by 1 March 1965.

3. Scientific Reports Published - A paper on instrument calibration is nearing completion and will be submitted to Applied Optics.

4. Papers Presented - None.

5. Visitors - None.

6. Travel - None.

7. Personnel Changes - None.

8. Important Property Acquired - None.

9. Fiscal Information - The estimated unencumbered balance remaining on 30 November 1964 was $32,500.

Submitted by:

H. D. Edwards
Principal Investigator

GEORGIA INSTITUTE OF TECHNOLOGY
Engineering Experiment Station
Atlanta, Georgia

QUARTERLY STATUS REPORT NO. 9

Contract Period: 1 December 1964 - 28 February 1965

Contract Number: AF 19(628)-2416
Georgia Tech Project No.: A-669

Contract Objective: Study of Natural Ultraviolet Backgrounds at High Altitudes

Contract Sponsor: Air Force Cambridge Research Laboratories
Office of Aerospace Research
United States Air Force
Bedford, Massachusetts

Principal Investigator: Howard D. Edwards

This report is intended only for the internal management uses of the contractor and the Air Force.

1. Investigations Being Undertaken

During the quarter project personnel were engaged in the following activities:

(a) Pointing control A major project of this quarter was the construction of a new pointing control amplifier. A printed circuit board was designed and constructed as a prototype to test the circuit for operation and temperature stability. The circuit performed as planned except the temperature stability was not as great as anticipated. At present, the amplifier is essentially stable over $\pm$ 15°C at ambient, and work is continuing to improve this temperature range.

(b) Detector head The detector head has essentially been reassembled with the following modifications: (1) the enclosure of the PM tube amplifiers in a thermostatically controlled (+ 90°F $\pm$ 3°F) oven, (2) the incorporation of the necessary relays and circuitry to perform in-flight calibration of the PM tube amplifiers, (3) the addition of a calibration light and the associated constant-current source to perform in-flight calibration of the photomultiplier tubes, and (4) the removal of the voltage regulator. Constant voltage is obtained through the thermostatically controlling of temperature of the silver cells, which have an essentially flat voltage vs discharge curve if the temperature is constant.

(c) Mechanical The major portion of mechanical reconstruction has been completed. Shock mounting is accomplished by two devices: (1) sufficient styrofoam beneath the gondola to completely cover the TM antenna and act as a crush pad for the whole gondola, and (2) the mounting of the spectrometer spider in 3 inches of styrofoam for additional vertical and horizontal shock mounting of the spectrometer.

(d) Electrical The rewiring of the spectrometer has begun and should be completed early this quarter.

(e) Data analysis and calibration The new calibration device has been completed. This new device permits a simpler calibration technique and is ideally suited for field calibration of the spectrometer. No additional work has been done in data analysis since major emphasis was placed on the preparation of the spectrometer for another flight.

2. Plans for Next Period

Mechanical and electrical reconstruction of the spectrometer should be completed during the first portion of the quarter. Work will continue on obtaining the desired temperature stability of the pointing control, and also work will be performed as to controlling the environmental temperature of critical components such as the pointing control and detector head. A flight is anticipated during the next quarter, and calibration should be completed before leaving for Holloman Air Force Base.

3. Scientific Reports Published

A paper entitled "Mathematical Description and Calibration of a UV Spectrometer-Polarimeter" by E. Hodgdon was submitted to the journal of Applied Optics.

4. Papers Presented - None.

5. Visitors - None.

6. Travel - None.

7. Personnel Changes - None.

8. Important Property Acquired - None.

9. Fiscal Information The estimated unencumbered balance remaining on February 28, 1965 was $26,900.

Submitted by:

H. D. Edwards
Principal Investigator

GEORGIA INSTITUTE OF TECHNOLOGY
Engineering Experiment Station
Atlanta, Georgia

QUARTERLY STATUS REPORT NO. 10

Contract Period: 1 March 1965 - 31 May 1965

Contract Number: AF 19(628)-2416
Georgia Tech Project No.: A-669

Contract Objective: Study of Natural Ultraviolet Backgrounds at High Altitudes

Contract Sponsor: Air Force Cambridge Research Laboratories
Office of Aerospace Research
United States Air Force
Bedford, Massachusetts

Principal Investigator: Howard D. Edwards

This report is intended only for the internal management uses of the contractor and the Air Force.

1. Investigations Being Undertaken

During the quarter project personnel were engaged in the following activities:

(a) Pointing Control The final design of the pointing control amplifier was constructed and tested under hot and cold conditions. A temperature stability equivalent to an input differential of less than 15 microvolts/^{o}C for a temperature range of 0^{o}C to 60^{o}C was obtained. A slight oscillation in the azimuth drive was corrected by incorporation of suitable capacitors in the negative feedback circuit of the amplifier.

(b) Detector Head The $\pm$ 9 volt Zener voltage regulator was reinstalled after it was felt that the characteristics of the silver cells made this regulator desirable. The detector head is now ready for flight.

(c) Electrical The rewiring of the spectrometer is complete and has been tested. A reduction in the number of available command channels necessitated a slight redesign of the on-off control circuitry. When the instrument is on, successive switch closures from a single switch will cause: first, turn-off of the pointing control; second, turn-on of the pointing control; third, turn-off of the entire system (excluding telemetry); and fourth, turn the entire system back on. The cycle is then repetitive.

(d) Telemetry During the later portion of the quarter, personnel from Northeastern University came to Georgia Tech to conduct telemetry installation and checkout. No problems were encountered.

(e) Mechanical The mechanical portion of the spectrometer is now ready for flight.

(f) Data Analysis and Calibration Decisions were made this quarter as to the form of the data that is desired from Telecomputing Services, Inc.

This consists of the four information channels (reference generator, grating position, PM #1, and PM #2) to be digitized at 500 samples/second for each channel, and the commutated channel to be digitized and plotted on CEC or Sanborn recorders.

2. Plans for Next Period

A flight is scheduled for the early portion of next quarter from Holloman A.F.B. Data analysis will commence as soon as data is received from Telecomputing, and an system evaluation will be conducted so as to improve and correct the entire system.

3. Scientific Reports Published

A paper entitled "Mathematical Description and Calibration of a UV Spectrometer-Polarimeter" by E. Hodgdon has been accepted for publication in the journal of Applied Optics.

4. Papers Presented - None.

5. Visitors - Mr. R. Toolin and Mr. J. Essex of Air Force Cambridge Research Laboratories and Mr. G. Nault of Northeastern University visited the project during May.

6. Travel - None.

7. Personnel Changes - None.

8. Important Property Acquired - None.

9. Fiscal Information - The estimated unencumbered balance remaining on May 31, 1965 was $15,700.

Submitted by:

H. D. Edwards
Principal Investigator

GEORGIA INSTITUTE OF TECHNOLOGY
Engineering Experiment Station
Atlanta, Georgia

QUARTERLY STATUS REPORT NO. 11

Contract Period: 1 June 1965-31 August 1965

Contract Number: AF 19(628)-2416
Georgia Tech Project No.: A-669

Contract Objective: Study of Natural Ultraviolet Backgrounds at High Altitudes

Contract Sponsor: Air Force Cambridge Research Laboratories
Office of Aerospace Research
United States Air Force
Bedford, Massachusetts

Principal Investigator: Howard D. Edwards

This report is intended only for the internal management uses of the contractor and the Air Force.

1. Investigations Being Undertaken

During the quarter project personnel were engaged in the following activities:

(a) Preflight The spectrometer and pointing control underwent their final checkouts at Georgia Tech and the spectrometer and gondola were made ready for transportation to Holloman Air Force Base, New Mexico. At Holloman Air Force Base the basic package (spectrometer, polarimeter, pointing control and associated equipment) was tested in the Stratosphere Chamber. An apparent loss of gain in the pointing control system necessitated two more environmental tests before the problem was alleviated. After the third test in the chamber, it was felt that the package was ready to fly. Telemetry tests were made with the co-operation of Land-Air, Inc. prior to the flight.

(b) Flight Weather caused a weeks postponement in the original launch day but the balloon was finally launched successfully on 1 July 1965 at 0442. After launch, it was noticed by using a theodolite that apparently something was hanging beneath the gondola. Project personnel then went to Jig-1 telemetry receiving site to observe the data as it was being received. The telemetry system suffered from the effects of the cold to the extent that the subcarrier oscillators drifted too far out of the allotted bands to allow for the recovery of the data. Float altitude (approximately 122,000 feet) was obtained at approximately 0810 and the telemetry system had warmed up sufficiently so that data could be recovered. It was noticed that although the pointing control was generating a sufficient differential clutch voltage, the yoke was not rotating. It was noticed that the spectrometer had stopped stepping. It was believed that the 500 ft. flag line between the parachute and gondola had become entangled in the spectrometer yoke assembly. Cutdown command was issued at 1350 and impact was in the Coolidge, Arizona area at 1445.

(c) Post-Flight According to the ground recovery crew, the flag line had tangled in the instrument to the extent that it had to be cut in order to remove the spectrometer. Major damage was sustained to the gondola and the spider support column upon impact. Minor damage such as dirty bearings, bent error sensor brackets, etc. was sustained as anticipated but should not be too difficult or time consuming to replace. If the pointing control had been able to operate there should have been no problem in maintaining an "on-sun" condition.

Telecomputing Services, Inc. received the data from the telemetry receiving site and began digitizing it as requested by Georgia Tech. This process was not completed until late in the quarter.

2. Plans for Next Period

Reconstruction of the flight package will continue with the hope of flying again as soon as possible. A new gondola and spider support column will have to be made or obtained and it is anticipated that a gondola can be made available from AFCRL. Data reduction will commense as soon as the digital tapes are received from Telecomputing Services, Inc. It is estimated that approximately 20-30 minutes of good "on-sun" data was received during the flight. This time is interspersed throughout the flight from ascent to cutdown. A new telemetry system is required for the next flight and detailed specifications for this new system are being made. No major changes in the basic flight configuration, pointing control, or detector head are anticipated.

3. Scientific Reports Published - None.

4. Papers Presented - None.

5. Visitors - None.

6. Travel - Project personnel were involved in the field trip to Holloman Air Force Base during June and July.

7. Personnel Changes - None.

8. Important Property Acquired - None.

9. Fiscal Information - The estimated unencumbered balance remaining on August 31, 1965 was $1,500.

Submitted by:

H. D. Edwards
Principal Investigator

AFCRL-66-397

A UV SPECTROPHOTOPOLARIMETER FOR THE STUDY OF NATURAL SKY BACKGROUNDS

by Ellis B. Hodgdon and H. D. Edwards

Contract No. AF19(628)-2416

Project No. 7621

Task No. 762102

FINAL REPORT

Period Covered: December 1962 through September 1965

Prepared for
Air Force Cambridge Research Laboratories
Office of Aerospace Research
United States Air Force
Bedford, Massachusetts

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Georgia Tech Project No. A-669
Engineering Experiment Station
GEORGIA INSTITUTE OF TECHNOLOGY
Atlanta, Georgia

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Abstract

This report documents the design, construction, and data reduction techniques of a balloon borne ultraviolet Ebert-Sekera spectrophotopolarimeter, whose purpose is to measure the natural sky backgrounds at altitudes greater than 100,000 feet. Considerable detail has been spent in describing the various mechanical, electrical and optical components of the system to serve as a guide for future improvements and alterations of the instrument. The data reduction section describes the various computer programs that have been necessary in order to reduce the large amount of data that is obtained. Intensity data at altitude has not been obtained as of yet, but the system has been shown to be capable of giving intensity and the Stokes parameters of the incident light.

Table of Contents

Table of Contents Con't

Table of Contents Con't

Page

List of Figures

List of Figures Con't

List of Figures Con't

List of Tables

Introduction

This report is a technical description of an ultraviolet (2000 to 4000 Å) spectrophotopolarimeter designed to measure the intensity and polarization of the natural sky backgrounds to an altitude of 120,000 feet. It was carried to this altitude by a 4.85 million cubic foot 3/4 mil polyethylene balloon, which was launched from Holloman Air Force Base, New Mexico and impacted in the Phoenix, Arizona, vicinity after a flight of approximately 10 hours. The spectrometer portion of the system is basically an Ebert-Fastie arrangement with a 50 cm. focal length mirror and theoretical f/5 optics.[1,2] The polarization measurement portion is essentially a Sekera polarimeter,[3-5] which consists of a rotating retardation plate followed optically by a linear polarizer, and the light passing through this linear polarizer is measured by a photomultiplier tube. By analyzing the AC components of the signal from the PM tube, the intensity and polarization parameters can be determined.

An important aspect of this experiment was the pointing control, which seeks the sun and locks onto it to provide a reference point for the spectrometer. The spectrometer steps in 15 degree increments, and for the 30 seconds that the spectrometer is stationary, at least one full wave length scan of 2000 to 4000 Å, which takes 20 seconds, is obtained. The data is telemetered to the ground and recorded and partially reduced by facilities provided by Holloman Air Force Base.

Although not directly connected with the hardware of the spectrophotopolarimeter, the data reduction techniques are also described in this report since they are necessary for obtaining any results from the experiment. The computer programs were written in Algol-60 specifically for the Burroughs B-5500 computer at the Georgia Institute of Technology, but flow charts are also given so that the basic logic can be followed even if one is not familiar with the programming language.

The actual balloon launch and flight is conducted by the Air Force Cambridge Research Laboratories (AFCRL) Balloon R and D Branch located in building 850, Holloman Air Force Base, New Mexico. All details of the launch are handled by their competent personnel, and they attempt to provide the contractor with all the services and aspects of the launch such as time, location, weather that are desired. The preflight checkout and balloon launch photographs are shown in figures 1 through 5. (These pictures were taken on two different days at different times in the morning, hence the difference in lighting conditions).

A general idea of the flight package can be gained from figures 6 and 7. These pictures show the spectrometer, yoke, and gondola just prior to launch and important features are pointed out. The various systems will be discussed in detail later, but a brief, cursory description is in order for an introduction.

In figure 6: The detector head contains all the components necessary to measure the amount of light passing through the exit slit of the spectrometer. The quarter wave plate drive mechanism provides a method of determining the polarization of the incident radiation. The sunshade limits the field of view of the spectrometer and eliminates some reflected light, and the guard cell sensors activate an auxiliary "semi-shutter" which reduces the light entering the spectrometer by approximately 2

Figure 1. Preflight Checkout.

Figure 2. Start of Inflation.

Figure 3. Near End of Inflation.

Figure 4. Balloon Launch.

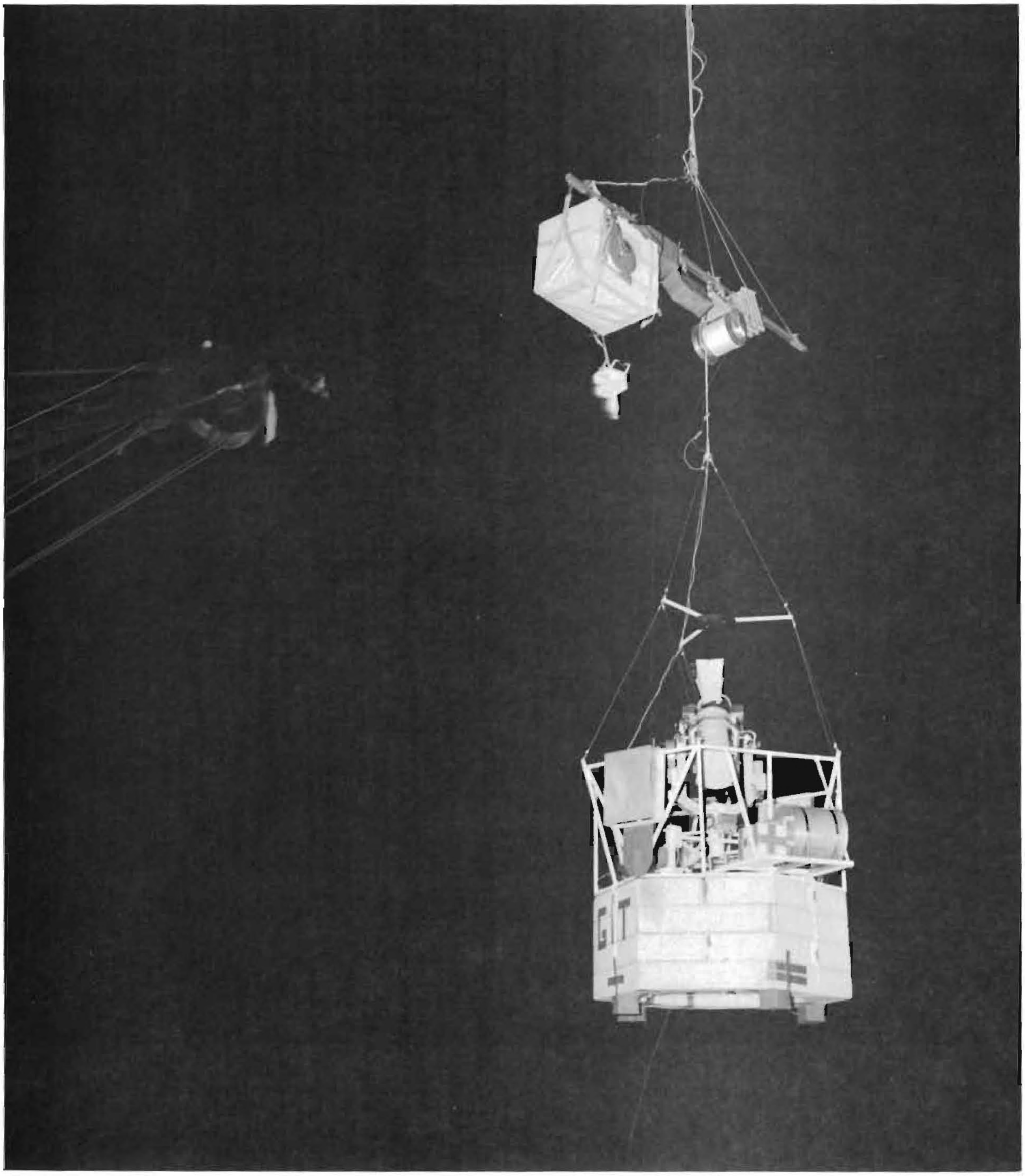


Figure 5. Gondola Launch.

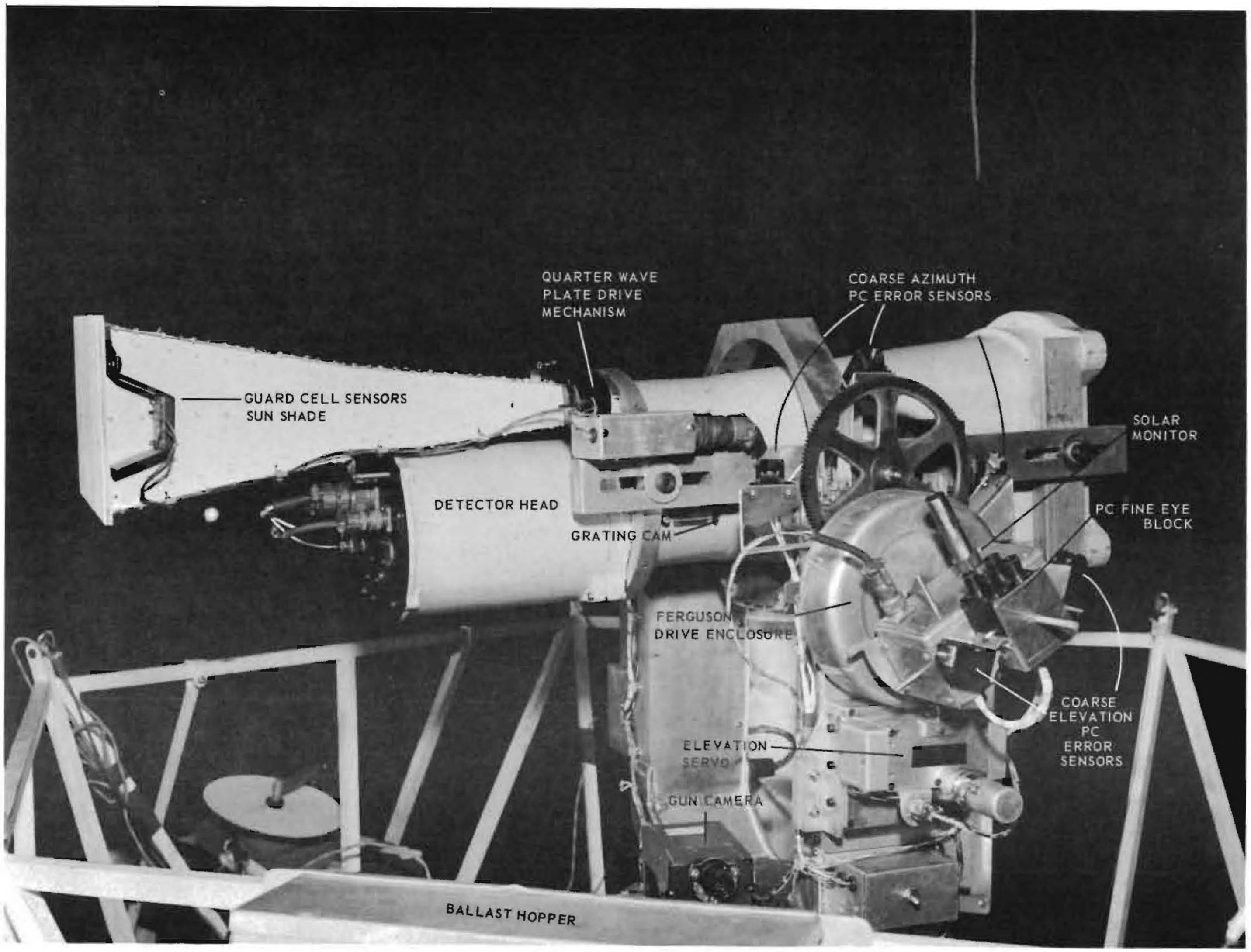


Figure 6. Spectrometer Showing Major Components.

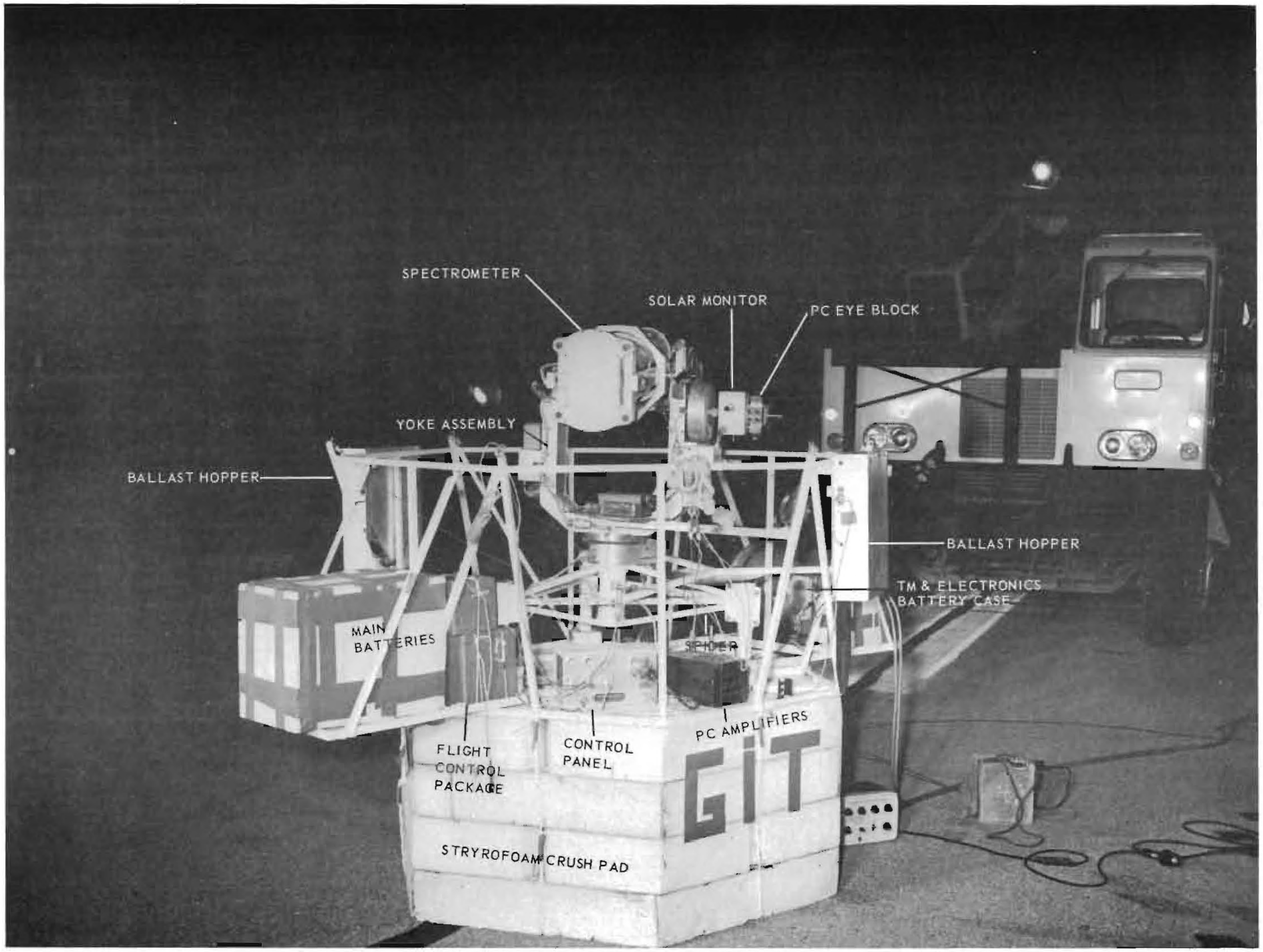


Figure 7. Gondola Showing Major Components.

orders of magnitude. The coarse PC (pointing control) sensors provide an error signal to the PC amplifier when the spectrometer is pointing considerably away from the sun, while the fine eye block provides the error signals for fine positioning of the spectrometer. The elevation servo provides the torque necessary to point the spectrometer system reference axis at the sun. The Ferguson stepping drive imparts to the spectrometer an intermittent motion of stationary for 30 seconds and moving 15 degrees in the next 30 seconds. The solar monitor provides a means of determining an "on-sun" condition and provides the reference axis from which the spectrometer steps.

For figure 7: The ballast hoppers, supplied by AFCRL, are one means of controlling the ascent rate of the balloon. The yoke assembly holds the spectrometer while the spider supports the yoke and provides some shock protection. The control panel serves as an electrical junction box and provides means of controlling some functions of the flight package and monitoring of some of the systems. The gun camera takes a picture every two minutes of the spectrometer through a convex rear view truck mirror to serve as a backup for the pointing control. The flight control package, also provided by AFCRL, provides three switch closures by radio command from the ground: drop ballast, telemetry on-off, spectrometer package on-off. The vehicle from which the package was launched can be seen in the background, and some of the equipment used during the pre-flight checkout can be seen on the ground beside the package.

History

Two actual flights have been made with the basic package, but both fell somewhat short of being a total success. The flight logs and directives for both flights are reproduced in Appendix A. The first flight, on 26 August 1964, was aborted shortly after reaching float altitude because of a premature failure of the electronics batteries and stoppage of the quarter-wave plate drive. The pointing control also failed to perform properly. Approximately eleven minutes of data was obtained, but this was not reduced since the maximum altitude of the data was in the order of 15,000 feet. The instrument on impact suffered major damage and the optics of the spectrometer were fouled by the transportation over unfavorable terrain back to the launch area.

The second flight, on 1 July 1965, was a bit more successful. After an abortive attempt the previous morning to launch a balloon that had a hole in it, the package was launched at 0442 MST. A slight mixup in instructions to Land Air, Inc. caused the data not to be recorded until some time after the actual launch. By this time, however, telemetry had seemed to drift sufficiently that the subcarrier discriminators could not recover the data, and so data was essentially lost until 0736 at an altitude of over 100,000 feet. A flight profile for the flight is shown in table I.

The FAA requires that flags be flown every fifty feet when the gondola and balloon are separated by a long load line. The device which was to deploy these flags singly as the gondola dropped beneath the balloon via the let down reel apparently malfunctioned and deployed all the flags before the gondola had dropped considerably. As a result, the flag line became entangled in the spectrometer yoke and prevented the pointing control from operating properly. This entangled flag line eventually became responsible for "blowing" a mechanical fuse in the stepping drive mechan-

Table 1

Actual Flight Profile

Flight Number: H65-63 Date: 1 July 65

Time-Mst	Height 10^3 Ft.	Latitude	Longitude
0442	GND		
0445	6.0		
0447	8.0		
0449	10.0		
0452:30	12.0		
0453:30	14.0		
0456	16.0		
0458:30	18.0		
0500	20.0		
0503	22.0		
0505	24.0		
0507	26.0		
0509:30	28.0		
0512	30.0		
0514	32.0		
0517	34.0		
0519	36.0		
0521:30	38.0		
0524	40.0		
0526	42.0		
0527:30	44.0		
0530	46.0		
0532	48.0		
0534	50.0		
0537	52.0		
0540:30	54.0		
0546	56.0		
0550:30	58.0		
0554	60.0		
0558	62.0		
0600		33°01'	106°02'
0602	64.0		
0606	66.0		
0609:30	68.0		
0614	70.0		
0615		33°00'	106°09'
0618:30	72.0		
0622:30	74.0		
0626	76.0		

Table 1 Cont.

Time-Mst	Height 10^3 Ft.	Latitude	Longitude
0637	82.0		
0640:30	84.0		
0645	86.0		
0645		$32^\circ 59'$	$106^\circ 22'$
0650	88.0		
0654:30	90.0		
0700	92.0	$32^\circ 59'$	$106^\circ 30'$
0704:30	94.0		
0710	96.0		
0715:30	98.0		
0715		$32^\circ 59'$	$106^\circ 41'$
0719	100.0		
0722:30	102.0		
0726	104.0		
0729	106.0		
0730		$33^\circ 01'$	$106^\circ 53'$
0733	108.0		
*0726	112.0		
0734	114.0		
0739	116.0		
0745	118.0		
0745		$33^\circ 00'$	$107^\circ 04'$
0746:30	120.0		
0751	122.0		
0800		$33^\circ 02'$	$107^\circ 15'$
0815		$33^\circ 02'$	$107^\circ 26'$
0830		$33^\circ 00'$	$107^\circ 41'$
0845		$32^\circ 58'$	$107^\circ 53'$
0900		$32^\circ 56'$	$108^\circ 05'$
0915		$32^\circ 53'$	$108^\circ 17'$
0930		$32^\circ 52$	$108^\circ 28'$
0945		$32^\circ 50'$	$108^\circ 38'$
1000		$32^\circ 49'$	$108^\circ 49'$
1015		$32^\circ 48'$	$109^\circ 01'$

*The next altitudes are determined by radar.

ism, so that the spectrometer was not stepping with respect to the sun after a certain time since this fuse, a sprocket chain, had snapped.

The quarter wave plate drive again stopped, but it was successfully restarted by turning off power to the entire system and then turning it back on. However, for a while, no polarization measurements and only relative intensities could be obtained, since it was unknown at what position the quarter-wave plate had stopped. Using the commutator data, it was discovered that the spectrometer had randomly found the sun for approximately one hour and forty-five minutes. This time is mainly after reaching float altitude, and an "on-sun" condition would occur when the gyrations of the gondola were such to bring the pointing control and solar monitor around to the sun. The pointing control amplifiers seemed to be producing a sufficient error signal, but the entanglement of the flag line prevented the servos from positioning the spectrometer properly.

Damage on impact was not as severe as the previous flight, but it did illustrate that more shock protection was necessary. The impact switches had failed to operate, so the load line was not severed. A gust of wind at impact caught the parachute and lifted the gondola into the air again, flipped it, and set it back down on its top and the spectrometer. The spider support column was broken at the welds, and there was considerable bent metal on various portions of the gondola and spectrometer.

The data was received and recorded on analog recorders by Land Air, Inc., which provides all the telemetry ground stations for Holloman Air Force Base. Personnel at Land Air are very cordial and are willing to cooperate fully with contractor personnel. Data reduction services are provided by Telecomputing Services, Inc. located at Holloman Air Force Base. These services include the decommutation of the commutator and digitizing the various subcarriers at specified rates. Present limitation of their electronic data conversion (EDC) equipment is a total of 1000 samples per second; i.e. 2 channels at 500 samples per second per channel, or 4 channels at 250 samples per second per channel, etc.

The first two flights, and especially the first flight, were instructive flights, and although some data was collected a more important function was the testing of the equipment and the debugging of the various systems. The basic design will remain fixed, and it is hoped that the few remaining defects to the system can be removed prior to the next flight. These defects include instability of the telemetry system, stoppage of the quarter wave plate drive, entanglement of the flag line, and better calibration circuitry.

The entire flight package can be broken down into three main subsections: mechanical, electronic, and optical, which are essentially self-explanatory. The description of the mechanical portion of the flight package is subdivided into the yoke assembly, the spectrometer and associated equipment, and the gondola and miscellaneous systems. The section on the electronics is subdivided into descriptions of the pointing control, detector head, control box, and miscellaneous circuitry. The optics section is subdivided into a description of the Ebert-Fastie optical system, the quarter wave plate theory and purpose, and alignment and calibration of the optical systems. A section on the somewhat vast problem of data analysis is also included to provide a starting point for further work in this field.

Mechanical Design

Yoke Assembly

Besides the basic function of supporting the spectrometer, the yoke assembly contains many other necessities for the proper operation of the system. Perhaps the two most important additional functions of the yoke are to hold the solar biaxial pointing control, which finds the sun and locks onto it, and the stepping drive, which determines the portion of the sky that is measured. Several other lesser functions are the mounting of gun camera, the location for several electronic circuits, and the monitoring of several pieces of information. The partial destruction of the yoke itself on the 26 August 1964 flight required that the bends of the yoke be strengthened to withstand more shock. Other than this modification, the basic yoke is shown in figure 8. The yoke is constructed from 5 x 2 x 0.125 wall 6063-T5 aluminum tubing, and the braces in the bends are 0.125 6063-T6 aluminum plate. The yoke is hollow, which allows for the placement of some gears inside the yoke and also reduces the weight.

The intermittent motion of the spectrometer is accomplished by a Ferguson drive assembly which is coupled by gears to the spectrometer. (see figure 10). The instrument is stepped in elevation in 15 degree steps and uses the elevation portion of the solar pointing mechanism to provide a solar reference point. The solar pointing mechanism is geared directly to a disc and causes it to rotate with the sun. A one RPM D-C motor is mounted on the disc and drives a stepping cam whose output shaft rotates 60° during 180° rotation of the input shaft and is stationary during the remaining 180°. This stepping cam performs a function similar to that of a Geneva drive except that the acceleration is near linear and the corresponding forces very small. The output shaft of the stepping cam is connected to the main shaft of the instrument through a 4:1 reduction and causes the instrument to step 15° in elevation during alternate 30 second intervals. Between steps the instrument is stationary and data is recorded during this period. When the instrument steps to 5° below the horizon, limit switches are engaged and reverse the power to the drive motor causing the instrument to be stepped in the opposite direction.

The pointing control elevation servo drives the stepping disc through a gear train (see Figure 9) and provides the reference position for the stepping mechanism, and the pointing control azimuth servo positions the spectrophotometer on a line through the sun. Therefore, a complete scan could be considered to start at 5° below the horizon, step up and pass through the sun to 5° below the opposite horizon and reverse to the starting horizon. The complete scan takes about 30 minutes, and during this 30 minutes, each portion of the sky is scanned twice.

A precision potentiometer (Beckman Helipot TSP R1K) provides a reading of the relative position between the spectrometer and the sun. The shaft of the potentiometer is fastened to the shaft on which the pointing control eye block is mounted and which provides the reference position for the Ferguson drive stepping mechanism. A sprocket mounted on the body of the potentiometer is chain driven by another sprocket mounted on the spectrometer support shaft (see figure 10) and thus the potentiometer body would be rotated with respect to the shaft, if the reference position remains fixed during a period of stepping motion. The potentiometer is part of a voltage divider network so that a voltage out of the network is related to the position between the sun and the spectrophotometer.

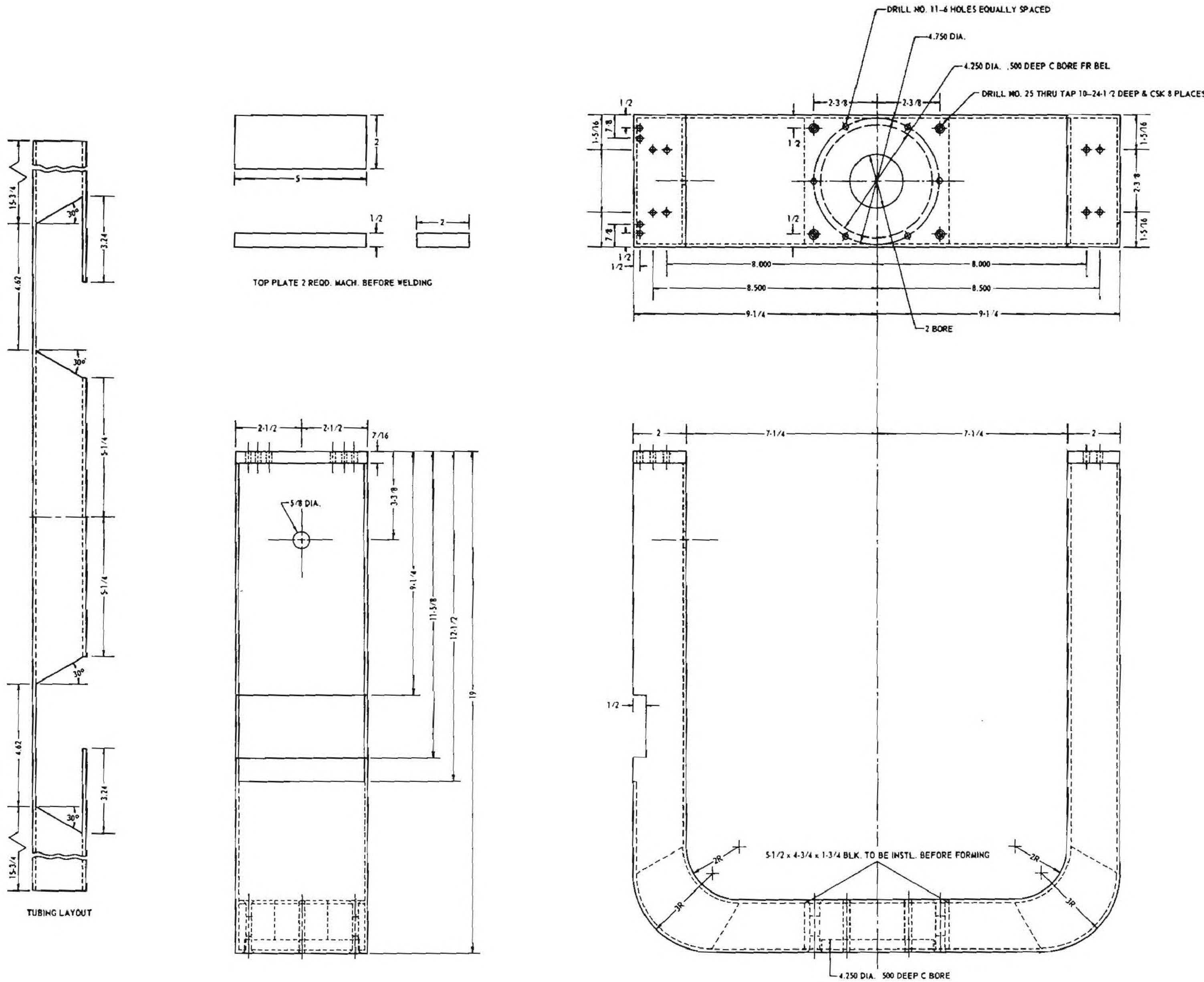


Figure 8. Original Drawing for Spectrometer Yoke.

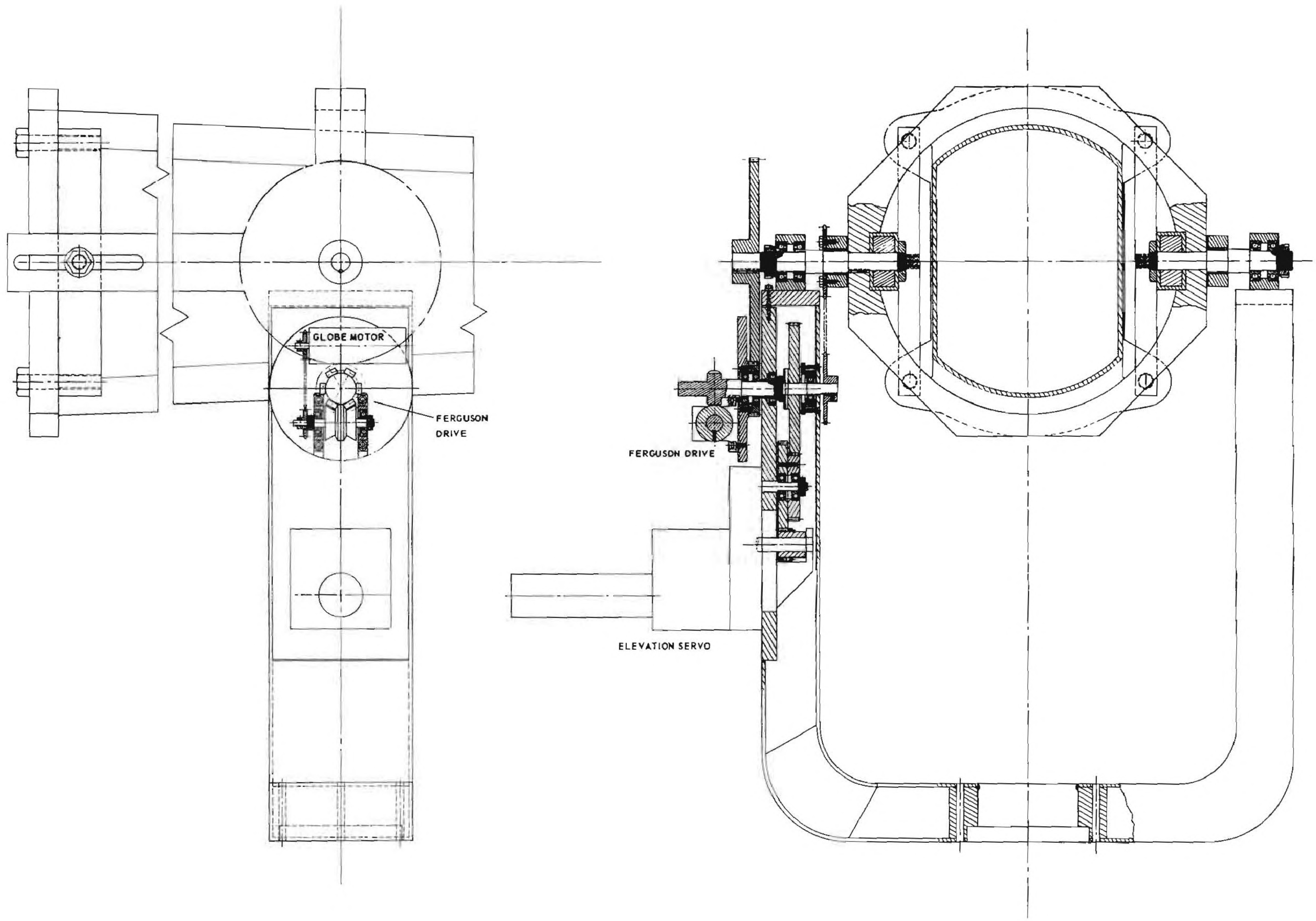


Figure 9. Spectrometer Drive System.

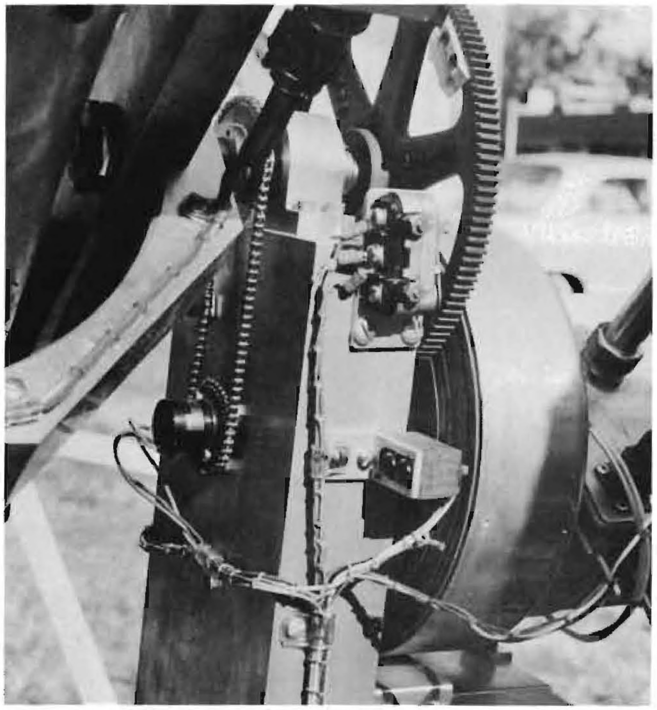


Figure 10. Spectrometer Drive and Elevation Scan Potentiometer.

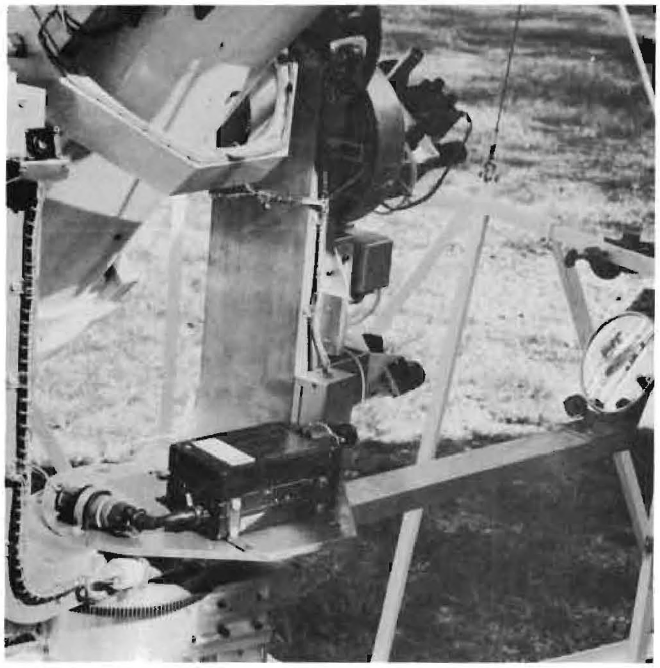


Figure 11. Gun Camera and Mirror.

A N-9 gun camera is mounted at the base of the yoke, and a convex truck mirror is mounted on an arm which extends from the base (see figure 11). During preliminary tests prior to the first flight, it was discovered that the pointer had "locked" onto something other than the sun (the actual cause was a defective coarse error sensor). It was felt that if this happened during the flight, useful data could still be obtained, if the position of the pointing control with respect to the sun was known. Therefore, to accomplish this, the gun camera was mounted so that it could take pictures every two minutes of the pointing control eye block, and the shadow sticks that were placed on the eye block would give an indication where the eye block was looking in relation to the sun. If the pointing control were functioning properly, then no shadow would be perceptible on the shadow stick on the front of the solar monitor-eye block assembly and the shadow sticks on the side and bottom would produce shadows which were perpendicular to the front surface. A scale was placed around each shadow stick so that a calibration could be obtained. For a view of the eye block from the camera position see figure 12.

The actual mount for the spectrometer is constructed for maximum strength and minimum weight. The spectrometer is fastened to two long aluminum bars by a ring which attaches to the spectrometer near the slit assembly and by two shorter bars which are attached at the mirror end. The long bars are slotted so that the drive axis can be adjusted to pass through the center of gravity. However, this adjustment can only be performed for a longitudinal shift in the center of mass; when the spectrometer axis is horizontal, the actual center of mass is either slightly above or below the driver axis.

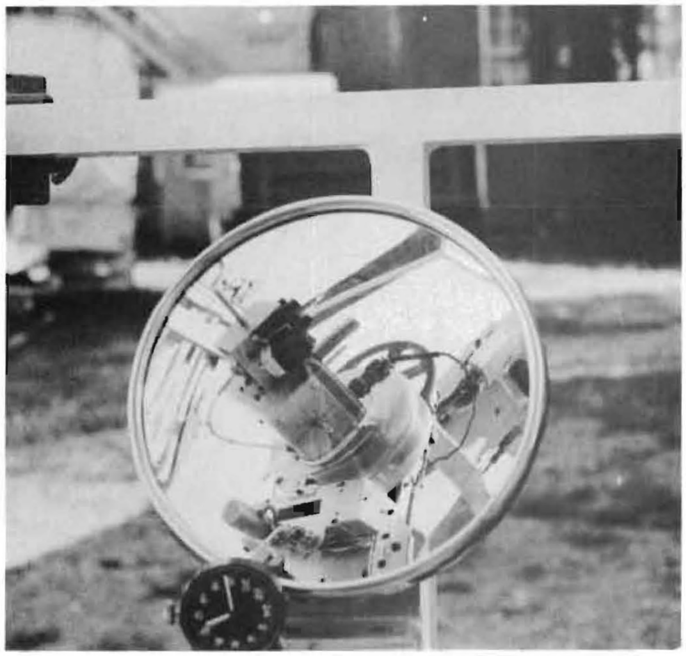


Figure 12. Camera View of Eye Block.

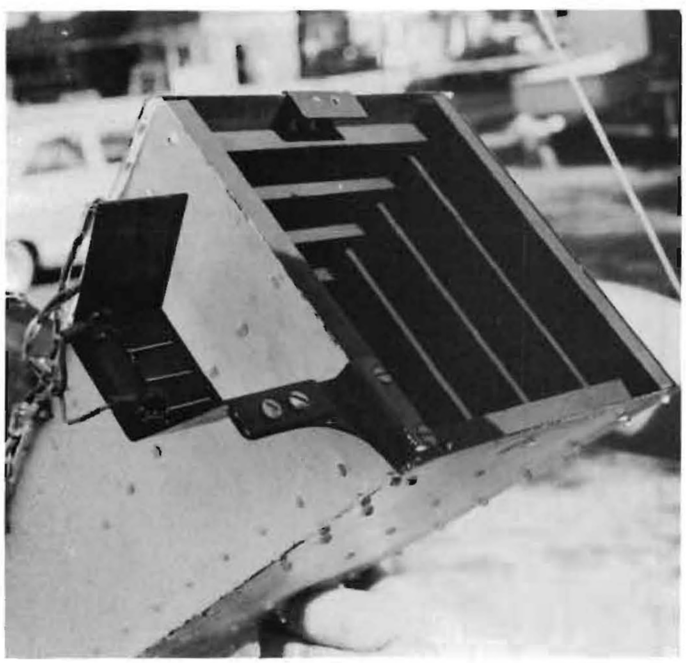


Figure 13. Sun Shade and Guard Cell Sensors.

The driver shaft which transmits motion from the stepping drive and the pointing control to the spectrometer is constructed from 5/8" stainless steel and is firmly attached to the driver gear (Boston YA-140) and the spectrometer mount by Woodruff keys on the shaft. The driven shaft, which only supports the spectrometer from the side opposite the driver shaft, does not have Woodruff keys since no power is transmitted through the coupling.

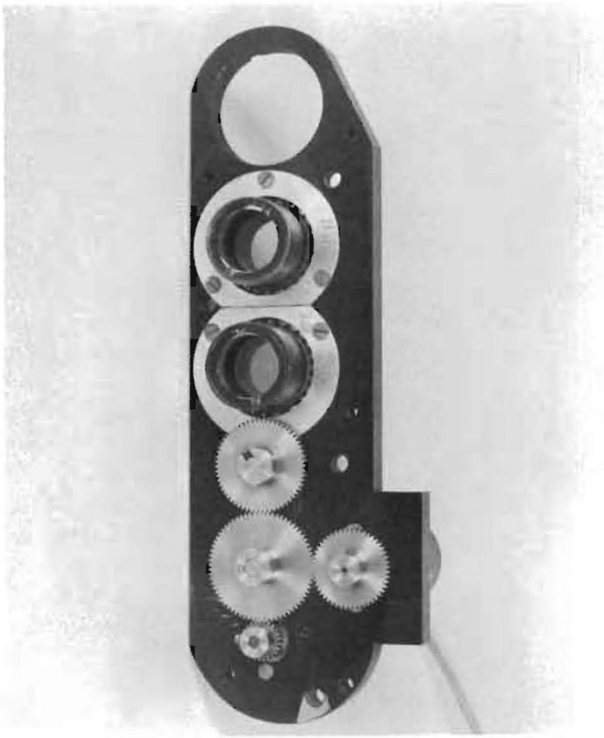
The pointing control elevation servo and the Ferguson stepping drive mechanism is mounted on an aluminum plate which is separate from the basic yoke. By means of a push-pull screw arrangement this plate can be raised or lowered with respect to the driver gear and permits an adjustment for the reduction of backlash in the gears. Another adjustment for the elimination of backlash is between the Ferguson cam and the cam follower-roller. Care must be exercised in both of these adjustments that differential thermal expansion will not freeze the components.

<u>Spectrometer</u>

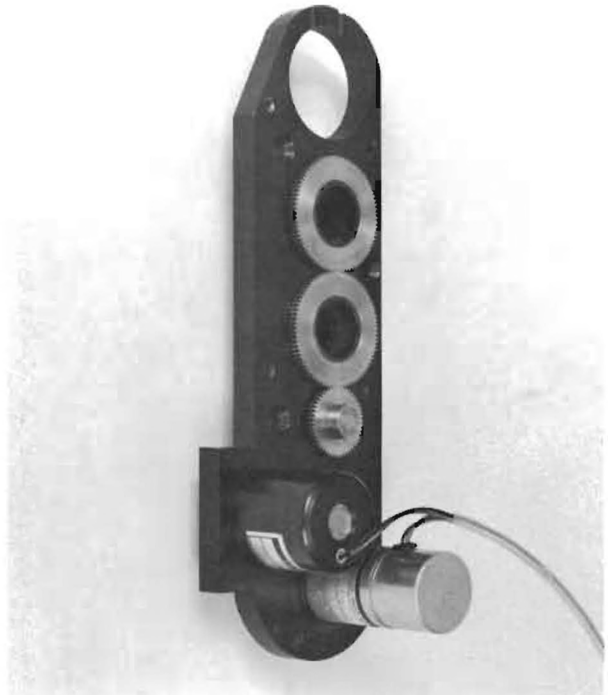
The basic spectrometer was purchased from Ray Lee Machine Company. As received from this company, the spectrometer contained the mirror, grating, grating drive motor, and detector head with photomultiplier tubes, DC-DC converter, amplifiers, and voltage regulator. Considerable work had to be done to make the basic spectrometer suited for the balloon flight, but the major optical work had already been done by the manufacturer.

Polarization was a problem from the beginning. The instrument in preliminary tests showed a strong polarization sensitivity, i.e. the output would depend upon the polarization of the incident light and more especially, upon the angle of incident polarized light. Therefore, since it was anticipated that the skylight would be polarized, in order to obtain meaningful intensity measurements, some method for measuring or eliminating the polarization had to be employed.

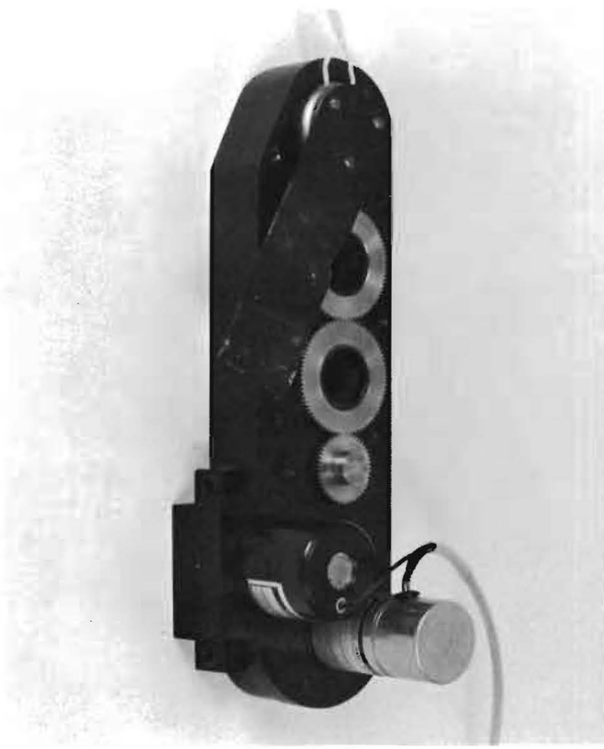
The method decided upon was similar to the polarimeter designed by Sekera of the University of California. This instrument consists of a rotating retardation plate ($\frac{1}{4}$ wave) in front of a fixed linear polarizer. The light passing through the linear polarizer is measured by a photomultiplier tube and would consist of a DC component and harmonics of twice and four times the fundamental rotational frequency of the retardation plate. The quarter wave plate drive mechanism was mounted directly in front of the entrance slit, and the motor which drives the retardation plates at 20 rps (1200 rpm) through a 4:1 gear reduction train is a Globe Industries type SS-4, #41A106-4, 27 VDC, 4800 RPM. Also coupled to this motor through a 2:1 reduction is an AC generator, or reference generator as it is sometimes called, Globe Industries Type SC, single phase, output voltage 1.5 volts per 1000 RPM, which provides an indication of the angular position of the quarter-wave plates. No attempt was made to set the generator so that 0° of the generator corresponded to 0° on both retardation plates, but a relative phase angle is determined during the calibration procedure. The bearings which are used in the drive mechanism are Fafnir A-539, in which are mounted the quarter-wave plate holders (see figure 14) and Barden #SR166W3, which are for the idler shafts. The bearings are cleaned of the original lubricant and relubricated with a low temperature silicon oil that can withstand the temperature extremes. The entire assembly is black anodized to reduce scattered light.



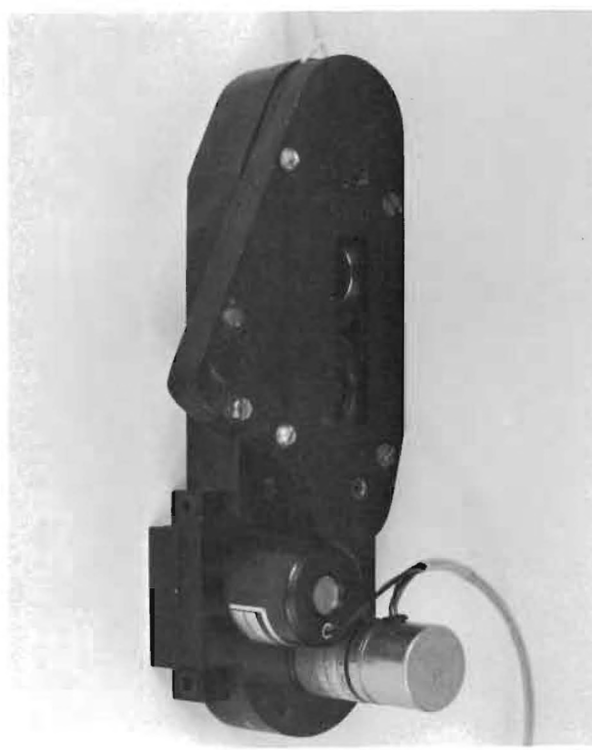
BOTTOM VIEW



TOP VIEW



TOP VIEW WITH SHUTTER



COMPLETE DRIVE SYSTEM

Figure 14. Quarter Wave Plate Drive.

The dynamic range of the photomultiplier amplifiers was about 10^4. However, it was calculated that a 10^6 dynamic range would be needed in order to measure all portions of the sky. Therefore, an auxiliary slit assembly was constructed as part of the quarter-wave plate drive to effectively reduce the length of the slit by a factor of 100. A small rotary solenoid (Ledex #H-2346-032) was attached to a thin aluminum blade onto which two sets of two additional peices of aluminum had been spot welded so that a 0.004" slit was formed. These 0.004" slits, when activated, would reduce the effective slit length from 1 cm. (0.4") to 0.01 cm (0.004") for each photomultiplier tube, and therefore, the sensitivity of the entire system would be reduced by approximately the desired factor of 100. The rotary solenoid was activated by three silicon solar cells (see figure 13) which were placed in a holder in such a way that when one of the cells was shaded (which corresponds to the spectrometer being more than 45° from the sun), its individual resistance was high enough to prevent sufficient current from flowing to activate a sensitive relay which controls the solenoid.

The grating mount is shown in figure 15. There is an aluminum box A which is slightly deeper than the thickness of the grating blank and into which the grating can be placed. Oppositely positioned nylon-tipped screws in all sides of the box hold the grating firmly. The position of these nylon-tipped screws has to be directly opposite so that no shearing moments are produced in the grating. In the bottom of the grating box are three nylon pads opposite brackets on the top edge of the box which support nylon-tipped screws to hold the grating to the holder firmly. The grating box A mounts on the grating shaft as shown so that the push-pull screws S,

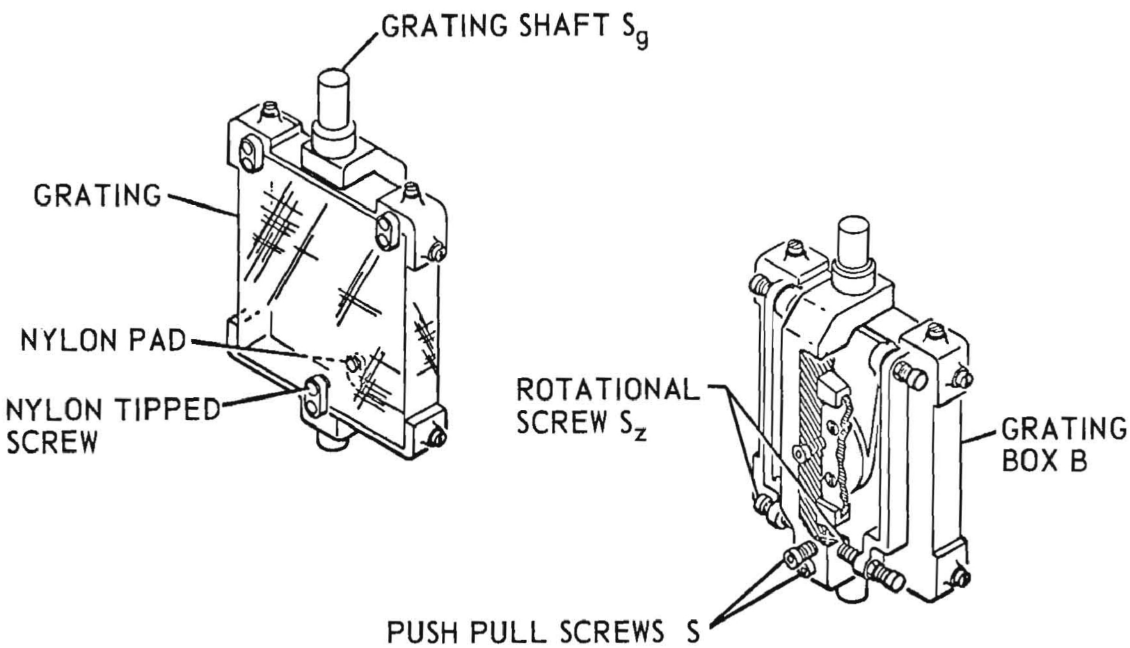


Figure 15. Grating Mount.

provide tilt motion, and the screws S_z provide rotation of the grating in its own planes. Access holes in the slit plate and the body of the spectrometer permit adjustment of these screws while the slit plate is on the instrument.

The ends of the grating shaft fit ball bearings which are mounted in bearing blocks which are fitted to the main housing. The bearings are cleaned with benzene and other organic solvents and are run dry throughout the flight. Since there is a small torque exerted by the grating cam, and the angular velocity is extremely slow, it was felt that more damage to the spectrometer was likely from outgassing of the bearing lubricants than from running the bearing dry.

The motor which drives the grating is mounted between the grating holder and the slit plate. The motor is a 28 volt, governed 3 RPM PM type motor (Globe Part No. 5A11251), and the cam which drives the cam follower attached to the grating shaft is cut so as to provide a 2000 Å sweep for the 2160 grooves/mm grating with a 75% forward scan and a 25% back scan.

Mounted underneath the grating cam are two ratchet type cams which activate miniature microswitches. One cam is cut so as to activate a microswitch (grating switch) four times with unequal intervals during the forward sweep of the grating, and the other cam is cut as to activate the other microswitch (calibration switch) two times during the return sweep of the grating. The grating switch produces a signal for the telemetry which can be converted into wave length after a suitable calibration spectrum is obtained. The calibration switch starts and stops the calibration sequence for the detector head. This arrangement needs some improvement prior to the next flight.

Gondola

The gondola mainly serves as a vehicle to carry the spectrometer aloft. The many associated functions necessary for the support of the spectrophotopolarimeter are conveniently mounted on the gondola. These functions include power, telemetry, and control among the more important ones. The gondola also serves an important function by providing a somewhat stable platform for the pointing control to work against. The gondola has two outriggers (see figure 16) which help to increase the moment of inertia of the gondola so that the ratios of the moments of inertias of the spectrometer to the gondola is better than 10 to 1. This basically means that for every clockwise revolution the spectrometer makes, it can be expected that the gondola would rotate about 1/10 revolution counterclockwise. A ratio of 10 to 1 has been found by High Altitude Instrument Company to be sufficient for most work. The main batteries and the pressurized battery container which houses the telemetry batteries and the electronics batteries constitute the major portion of the weight and are mounted external to the gondola on the outriggers as mentioned before. The pointing control, control panel, intervalometer housing, and telemetry have small mass and are mounted internally (see figure 7). The gondola, which is constructed from 1" square aluminum tubing and welded, is designed for maximum strength, minimum weight, and large moment of inertia.

The gondola also serves as a mount for the ground plane for the telemetry antenna. A sheet of H-3034 0.050" aluminum serves as a ground plane and completely covers the bottom of the gondola. For the 26 August flight, it was found that this was necessary to prevent the RF energy radiated from the antenna from interfering with the sensitive pointing control

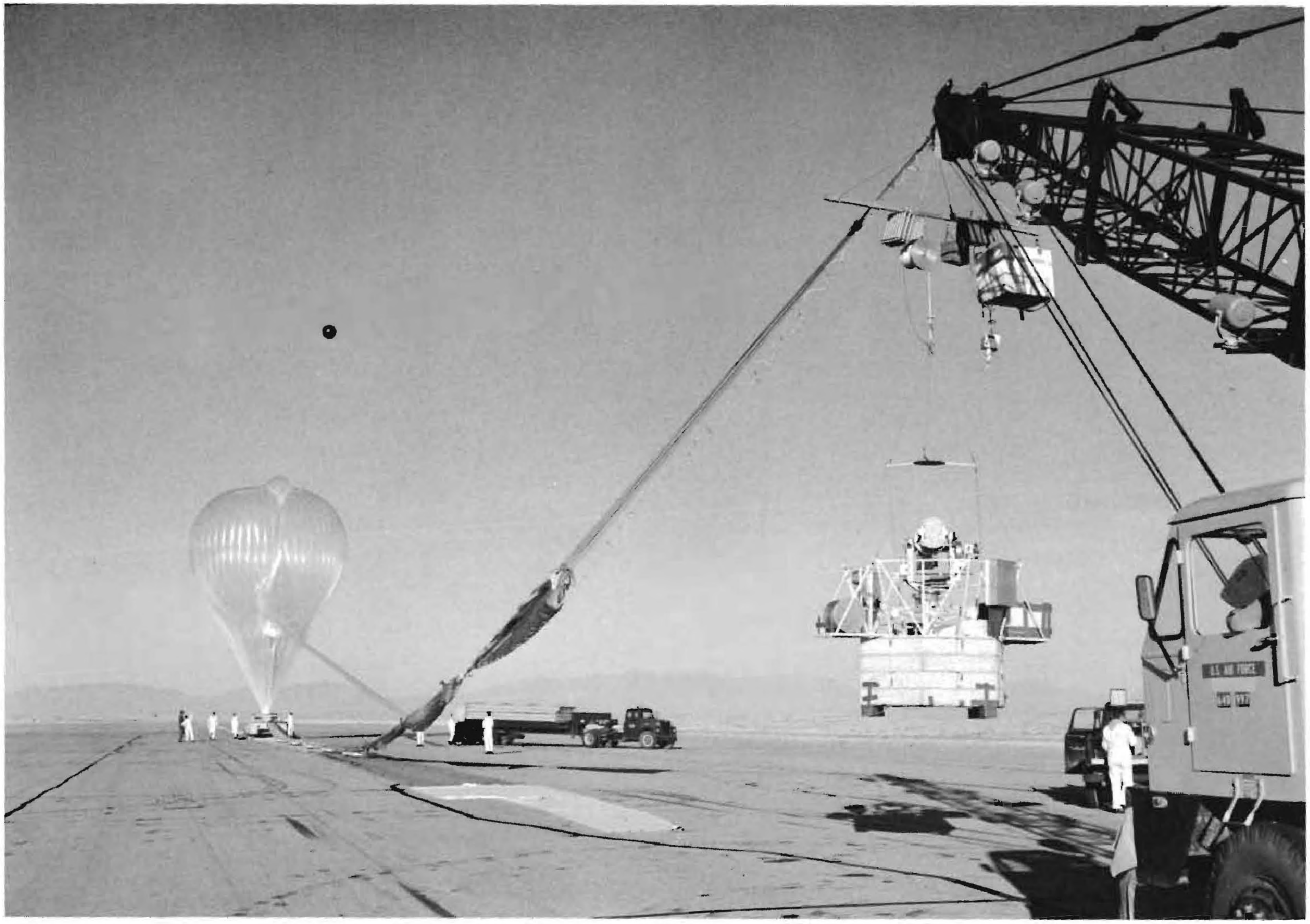


Figure 16. Balloon Package Prior to Launch Showing Flight Configuration and Gondola Outriggers.

amplifiers; however, after redesigning the amplifiers, RF interference was no longer a problem, but the ground plane remained as it was. The telemetry antenna is mounted in the center of this ground plane and extends approximately 22" below the gondola proper. For the 1 July flight, 24" of low density styrofoam was placed beneath the gondola to help absorb shock and to prevent the gondola from striking the almost rigid telemetry antenna.

The various control boxes and cases are mounted around the circumference of the gondola in order to increase the moment of inertia slightly and for convenience. No extra care was observed in balancing the gondola since on the first flight this was not a serious problem; however, components were not overloaded on one side but spaced to give a rough balance. The telemetry system was mounted close to the center of the gondola so that the coax for the antenna would reach.

A three legged spider support holds the spectrometer and yoke assembly and is designed to provide some shock protection. The legs of the spider were mounted in three inches of dense styrofoam, and the support members were free to slide on the spider legs. The column of the spider support contains two sets of slip rings which provide electrical power to the yoke assembly, and provide a means of obtaining signals from the different sensors on the yoke and spectrometer (photomultiplier tubes included). Also mounted within the support column is the azimuth position potentiometer, which measures the relative angle between the spectrometer yoke and the gondola. The pointing control azimuth servo is mounted on the support column, and the two counterdriving gears engage a large gear attached to the spectrometer yoke.

A battery box was built to contain the electronics batteries (24 volts center tapped) and the telemetry batteries (7.5 volts at 60 ampere-hours) that could be pressurized and the temperature of the batteries maintained. The telemetry batteries did not necessarily require temperature compensation, but it was felt that the electronics batteries, which supply voltage to the detector head, would be more stable if the temperature were maintained within reasonable limits. Also contained in this battery box are the necessary internal-external relays and the connections for the umbilical cable to supply power for testing and prior to flight.

Arising from the six points of the hexagon shaped gondola are the support wires, which are terminated in pairs at a Y-spreader above the gondola. Attached to this Y-spreader is the balloon shield, a peice of black anodized aluminum which prevents the spectrometer from observing the balloon or scattered light from it. Steel cables from each of the three arms of the Y-spreader form the upper portion of the A-frame cabling and are terminated in a D-ring to which the balloon is eventually attached (see figure 16). The overall dimensions of the gondola itself are 66" across the flats of the hexagon, 71" maximum (across opposite points), and 28.5" deep. The outriggers extend 18" outside the gondola on opposite sides. The six lower cables are each 43" long, attach to the gondola 35.5" apart and are attached in pairs to the Y-spreader. The three upper cables are each 48" long and are attached to the Y-spreader 34.6" apart. The overall height of the gondola (excluding telemetry antenna) is approximately 10 feet.

Prior to the flight, AFCRL personnel attach various components to the package which include ballast hoppers, a flight control package which provides the remote control of the package, and impact switches and control. These packages can be used just prior to flight to bring the package into static equilibrium so detailed planning beforehand is not particularly necessary.

The basic mechanical configuration has proven to be correct, although minor changes are necessary to improve the design. It is anticipated that a new gondola design will be used on the future flight which provides better shock protection. Failure of the impact switches to operate on the 1 July flight caused the entire package to be subjected to undue stress and caused some damage that was not anticipated.

Electronics

Detector head

The detector head is perhaps the most important single assembly on the instrument. This assembly converts the light that passes through the exit slit of the spectrometer into a current, amplifies it, and provides a signal which can drive the telemetry subcarrier oscillators. Also, included in the detector head are the power supplies, ovens, temperature sensors, and calibration devices, which are necessary for the proper operation of the assembly. The airtight construction of the detector head (see figure 17) is such that it will maintain a nominal one atmosphere pressure inside even at altitude so that the high voltage (approximately 3000 volts) will not arc. Light enters the detector head through a quartz window which is sealed with O-rings, and all the electrical connectors are also sealed with O-rings and are the type that can withstand the pressure differential and have a small leakage rate. Two access ports are included which permit compensation for photomultiplier dark current and for the

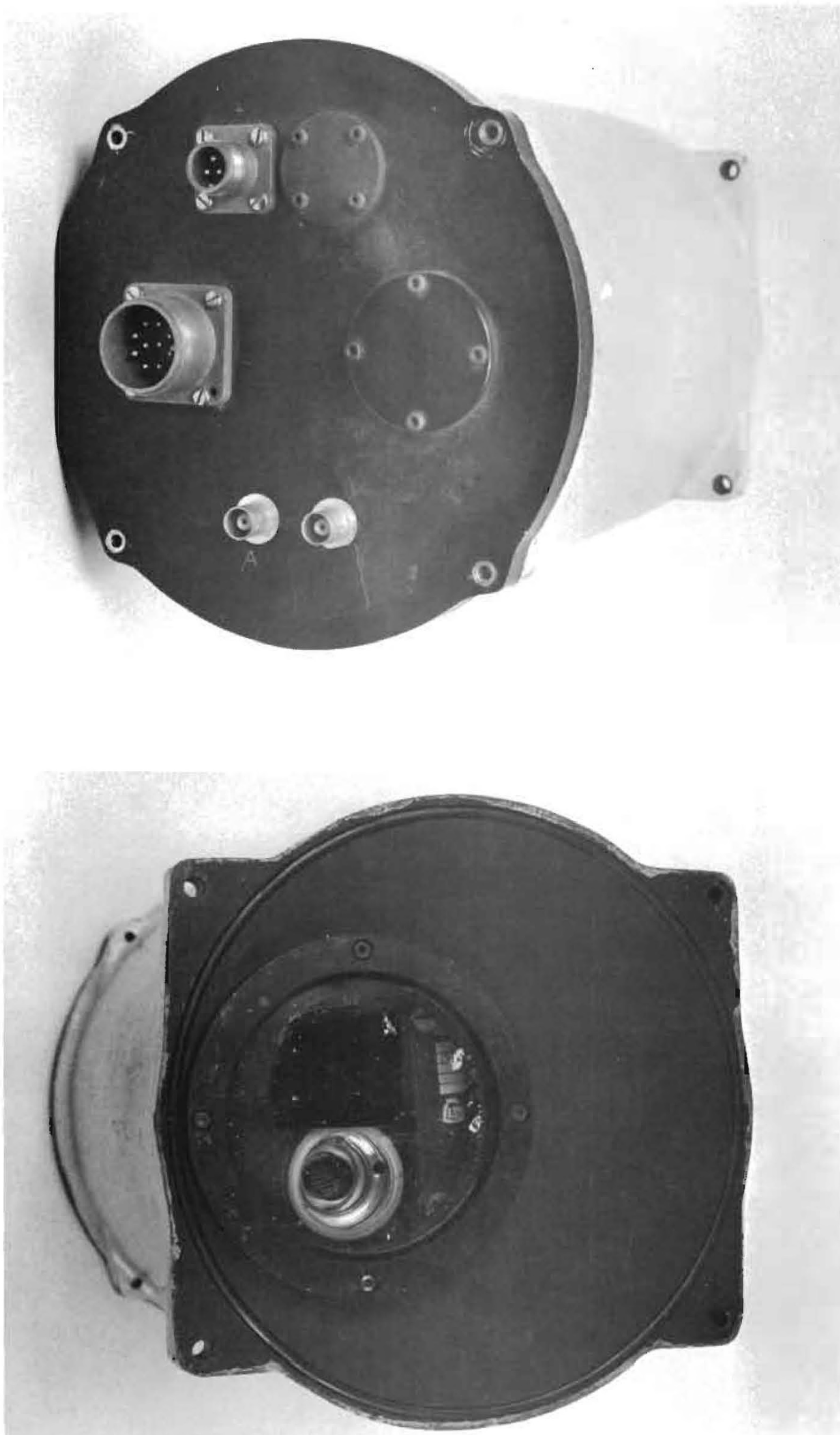


Figure 17. Outside View of Detector Head.

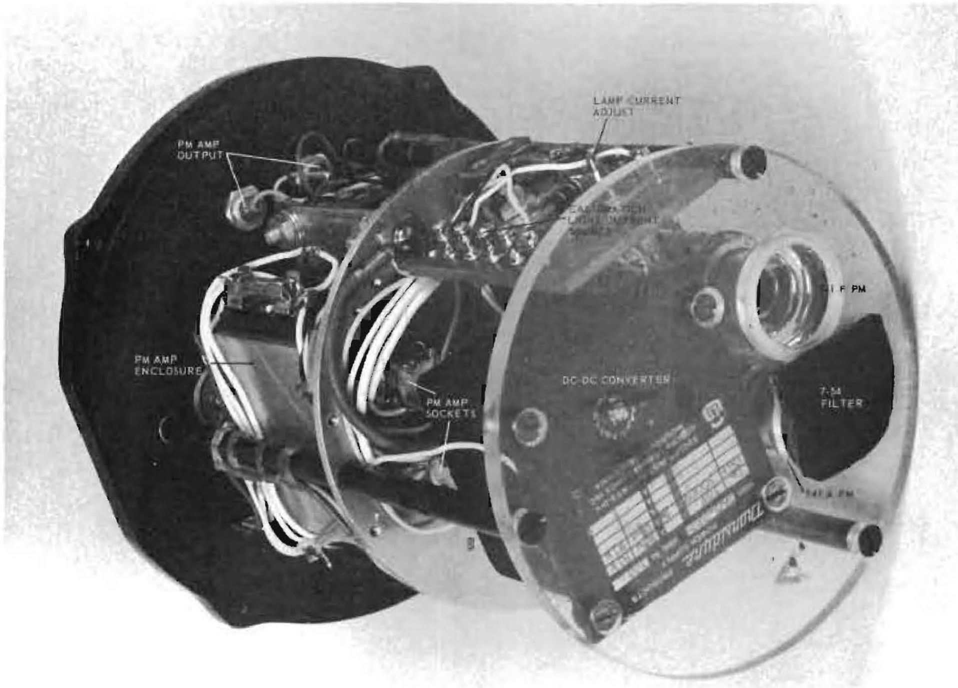


Figure 18. Inside View of Detector Head.

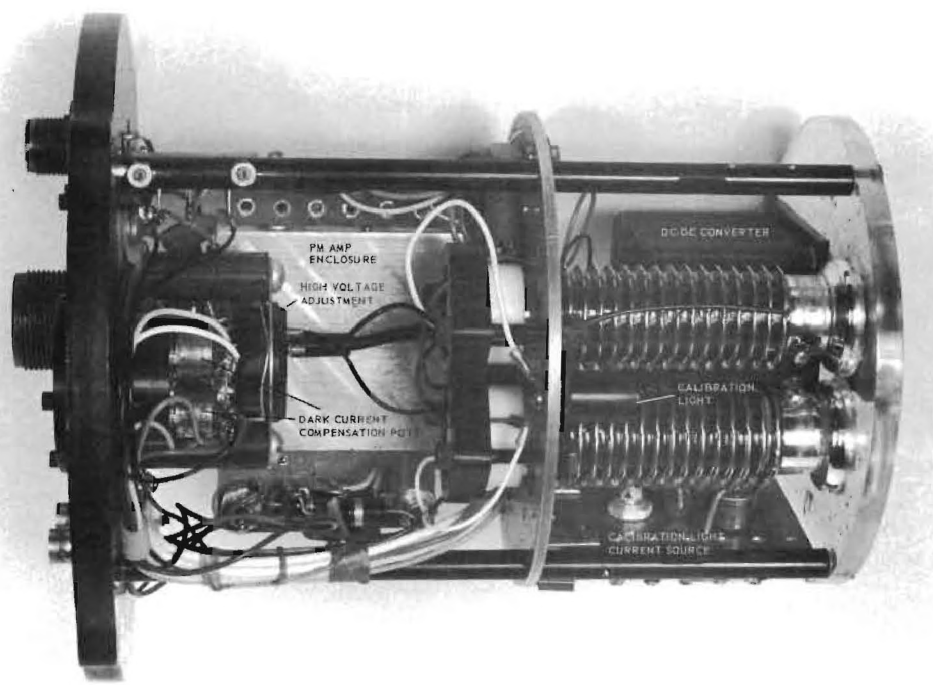


Figure 19. Inside View of Detector Head.

adjustment of the zero level for the calibration sequence. The latter port is also used for pressurizing the detector head to test for leaks. To provide thermal isolation, the inside of the detector head wall is lined with $\frac{1}{2}$" styrofoam which has been soaked in shellac to prevent crumbling. The basic configuration for the electronic components can be seen in figure 18.

Photomultiplier Tubes

Two photomultiplier tubes are used in the detector head in order to adequately cover the 2000 to 4000 Å wave length spread. Each tube is a 14 stage, end-on type with a saphire window, manufactured by Electro-Mechanical Research, Inc., Princeton Division (Ascop). The PM tube intended primarily for the 3000 to 4000 Å region that was flown was a type 541A-05M-14-03900, which has a cesium-antimony photocathode, and the PM tube intended primarily for the 2000 to 3000 Å region that was flown was a type 541F-05M-14-03900, which has a cesium-telluride photocathode and is considered to be "solar blind", i.e., insensitive to intensity of wave lengths longer than 3500 Å.

The two unpotted photomultiplier tubes are mounted in the detector head so that their photocathodes are over a portion of the exit slit of the spectrometer. The tubes out of necessity have to be unpotted since the size of the potted photomultiplier tube is such that both tubes could not fit over the exit slit of the spectrometer and some other arrangement would be necessary. The tubes are separated from the Lucite base plate of the detector head by nylon spacers, and are held securely in position by a nylon cup at the anode end of the PM tube which is held by a metal collet fastened to the middle plate of the detector head (see figure 19).

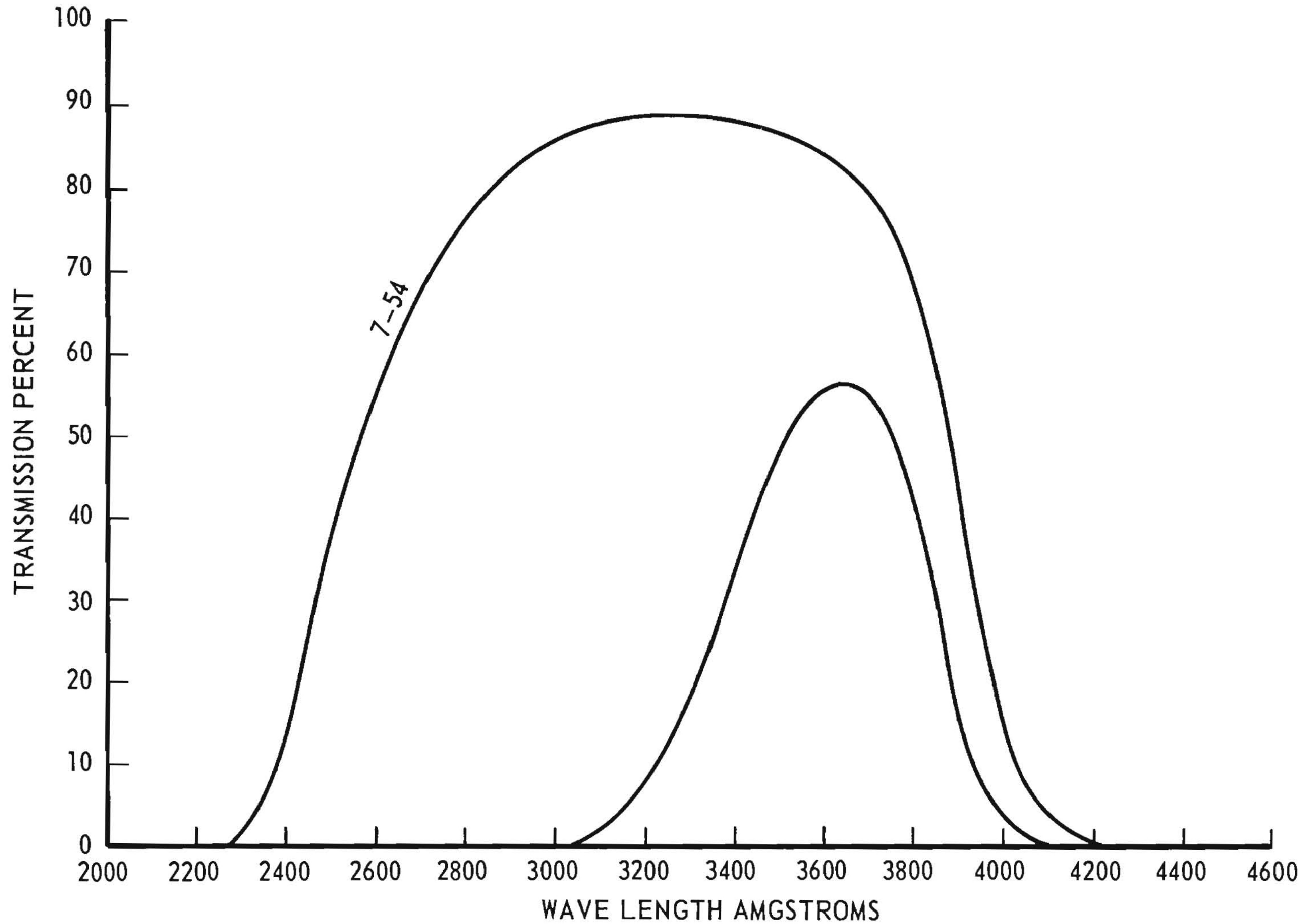


Figure 20. Transmission of Corning 7-54 Filter.

To prevent scattered visible light from interfering with the measurements of low intensity (say around 3000 Å), a Corning #7-54 ultraviolet transmitting, visible absorbing filter is placed between the exit slit and the 541A PM tube by cementing to the Lucite base plate of the detector head. This filter has a typical transmittance curve as shown in figure 20 and is ideally suited to its function.

The two photomultiplier tubes, as expected, show different gain, spectral, and dark current characteristics. Reproductions of the manufactuer's data sheets for the 541A tube are shown in figures 21, 22, and 23, while the data sheets for the 541F tube are shown in figures 24, 25, and 26.

Photomultiplier tube dark current is compensated by a potentiometer associated with the PM tube amplifiers. Thus, theoretically, it would be possible to adjust these pots so that zero signal out would correspond to zero light into the PM tubes. In practice, this is attempted, although such items as temperature variation and electro-magnetic fields influence the value of the dark current.

DC to DC Converter

The Edcliff Instruments DC to DC converter is shown in figure 27, and consists of a push-pull transistor oscillator that uses a saturating transformer. The transformer has a secondary winding that supplies a silicon diode rectifier connected in a voltage doubler circuit. Because the collector current of the transistors consist of large pulses of current, a filter should be used to prevent fluctuation in the power supply voltage, although one was not used during the flight even though there was some ripple on the power supply voltage caused by the DC to DC converter.

E M R

PRINCETON DIVISION
ELECTRO-MECHANICAL RESEARCH, INC.
Phone: 609-799-1000 * Princeton, N. J. * TWX: 609-799-0265

ASCOP SPECIFICATION 541A-05M-14-03900 SERIAL NO. 4489

SUMMARY DATA SHEET

CHARACTERISTICS

Spectral response: see attached curve

Cathode radiant sensitivity at 4100 Å	53.5	$\times 10^{-3}$ A/W
Cathode quantum efficiency at 4100 Å	16.2	%
Cathode radiant sensitivity at 2537 Å	31.0	$\times 10^{-3}$ A/W
Cathode quantum efficiency at 2537 Å	15.2	%
Average Luminous sensitivity:	66	μA/lumen

Current amplification[1,2]: see attached curve

Amplification 10^5 at	1580 volts	[2]Dark Current	1.2×10^{-10} A
Amplification 10^6 at	2150 volts	Dark Current	1.7×10^{-9} A
Amplification 10^7 at	2950 volts	Dark Current	1.7×10^{-8} A
Amplification 10^8 at	volts	Dark Current	A

MAXIMUM OPERATIONAL RATINGS

Supply Voltage: 3600 volts at 20°C

MAXIMUM RATINGS (ABSOLUTE-MAXIMUM VALUES)

Supply Voltage	3600 volts
Anode Current	1 ma
Temperature:	75° C

REMARKS

"Tubes shipped without potting may not exhibit the normal dark current characteristics due to surface leakage effects. Electro-Mechanical Research, Inc. is therefore unable to extend any guarantee regarding dark current in such cases."

NOTES

NA: Not Applicable

[1]See schematic diagram for voltage distribution

[2]Measured at 20° C

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on 8-21-64

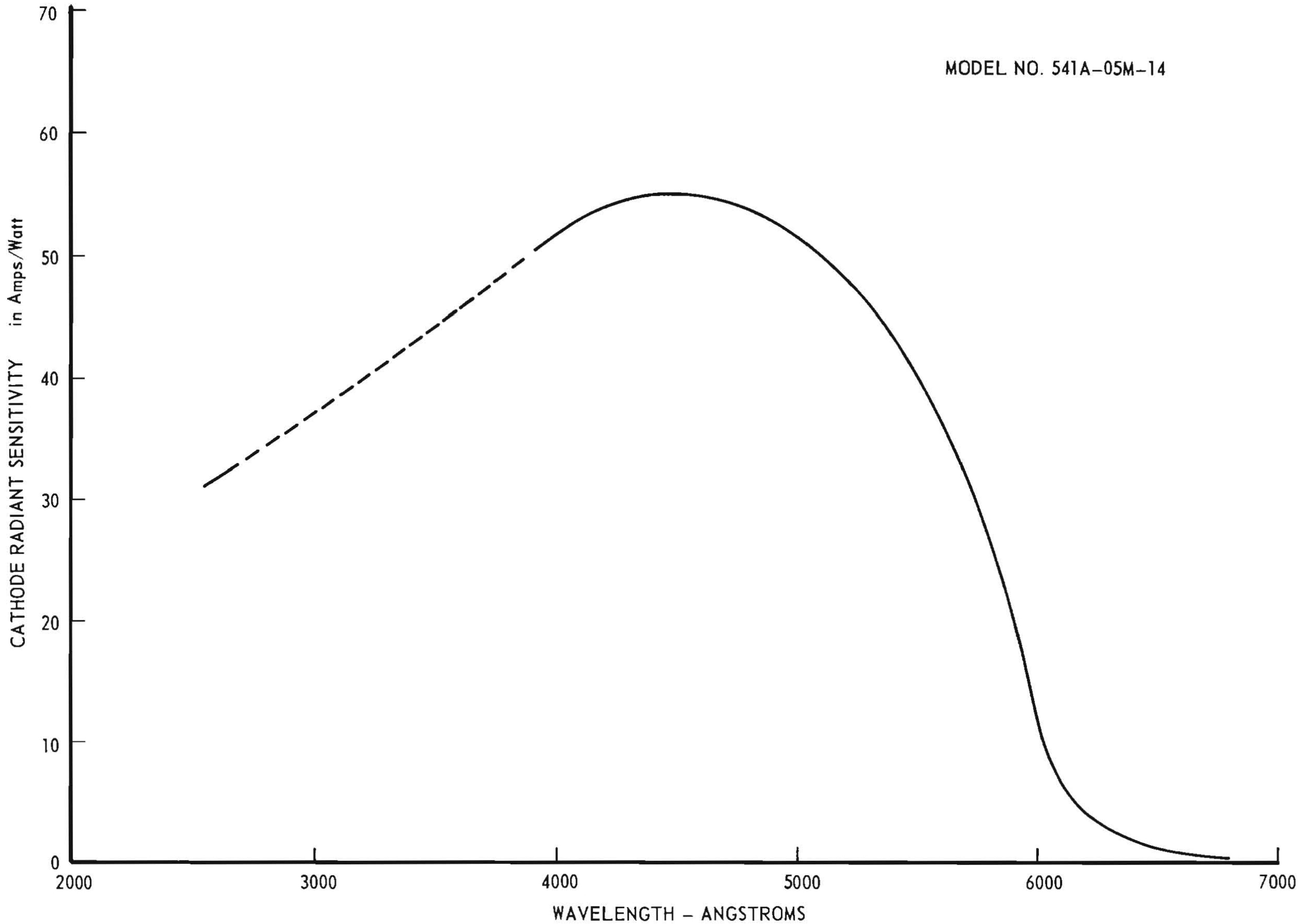

Figure 22. Photomultiplier Spectral Response.

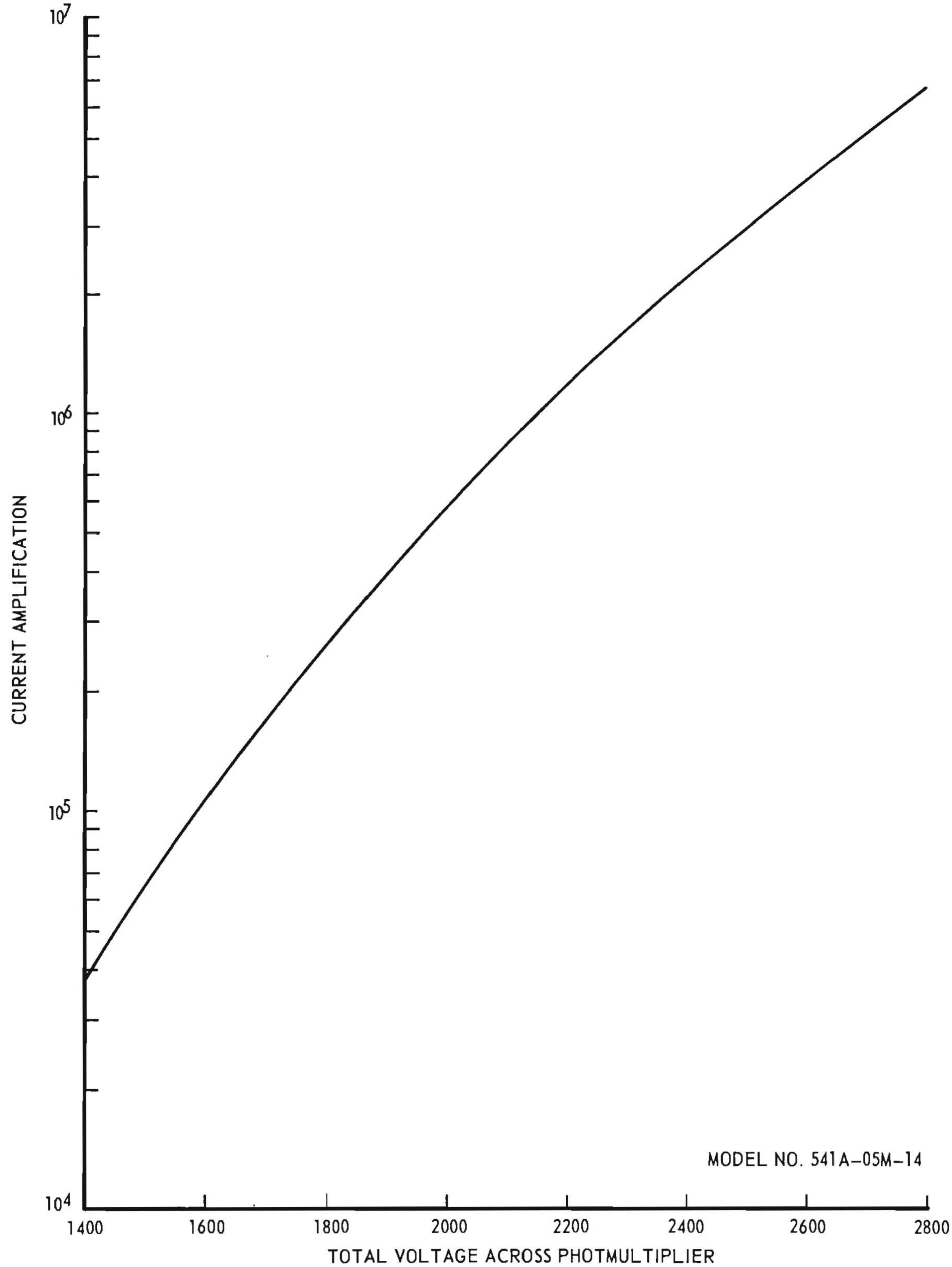

Figure 23. Dependence of Current Amplification on Voltage.

E M R

ELECTRO-MECHANICAL RESEARCH, INC.

Executive Offices
Sarasota, Florida

ASCOP Division
Princeton, New Jersey

Swinburne 9-1000
TWX-Plainsboro 591

Princeton, New Jersey
P. O. Box 44

ASCOP Photomultiplier Tube

Model No. 541F-05M - 14-03900

Serial No. 435

Photocathode: Cs-Te "solar blind"

SUMMARY DATA SHEET

Window material: Sapphire Thickness: .040" Supplier: Linde

CATHODE CHARACTERISTICS (see also attached spectral response curve):

Quantum efficiency at 2537 Å: 5 %
Quantum efficiency at 3650 Å : 2.8 x 10^{-3}%

MULTIPLIER CHARACTERISTICS (see also attached electron multiplication curve):

Number of stages: 14
Amplification 10^5 at 1940 volts Dark Current 2 x 10^{-12} amperes
Amplification 10^6 at 2675 volts Dark Current 1.2 x 10^{-11} amperes
Amplification 5 x 10^6 3340 volts Dark Current 6 x 10^{-11} amperes

WIRING DIAGRAM (see enclosed print):

Resistors: equal value 3.9 Megohms after first dynode
Cathode - 1st dynode: 3.9 Megohms
Minimum cathode - 1st dynode voltage: 100

Colar Code - Cathode: Black
1st dynode:
+ HV: White
Signal: Red

REMARKS

Sale of unpotted tube voids performance warranty.

Inspected by

On 11-16-62

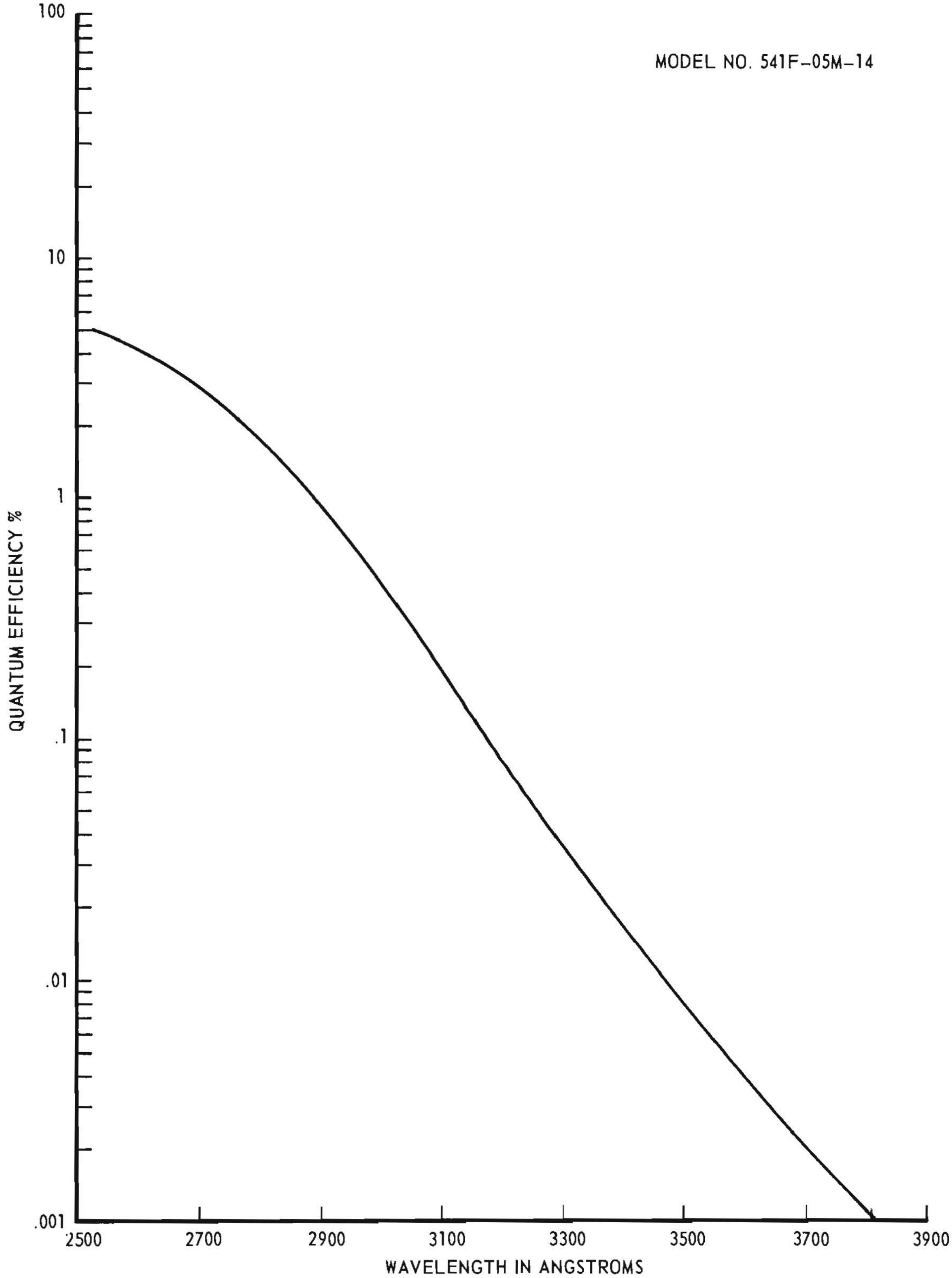

Figure 25. Photomultiplier Spectral Response.

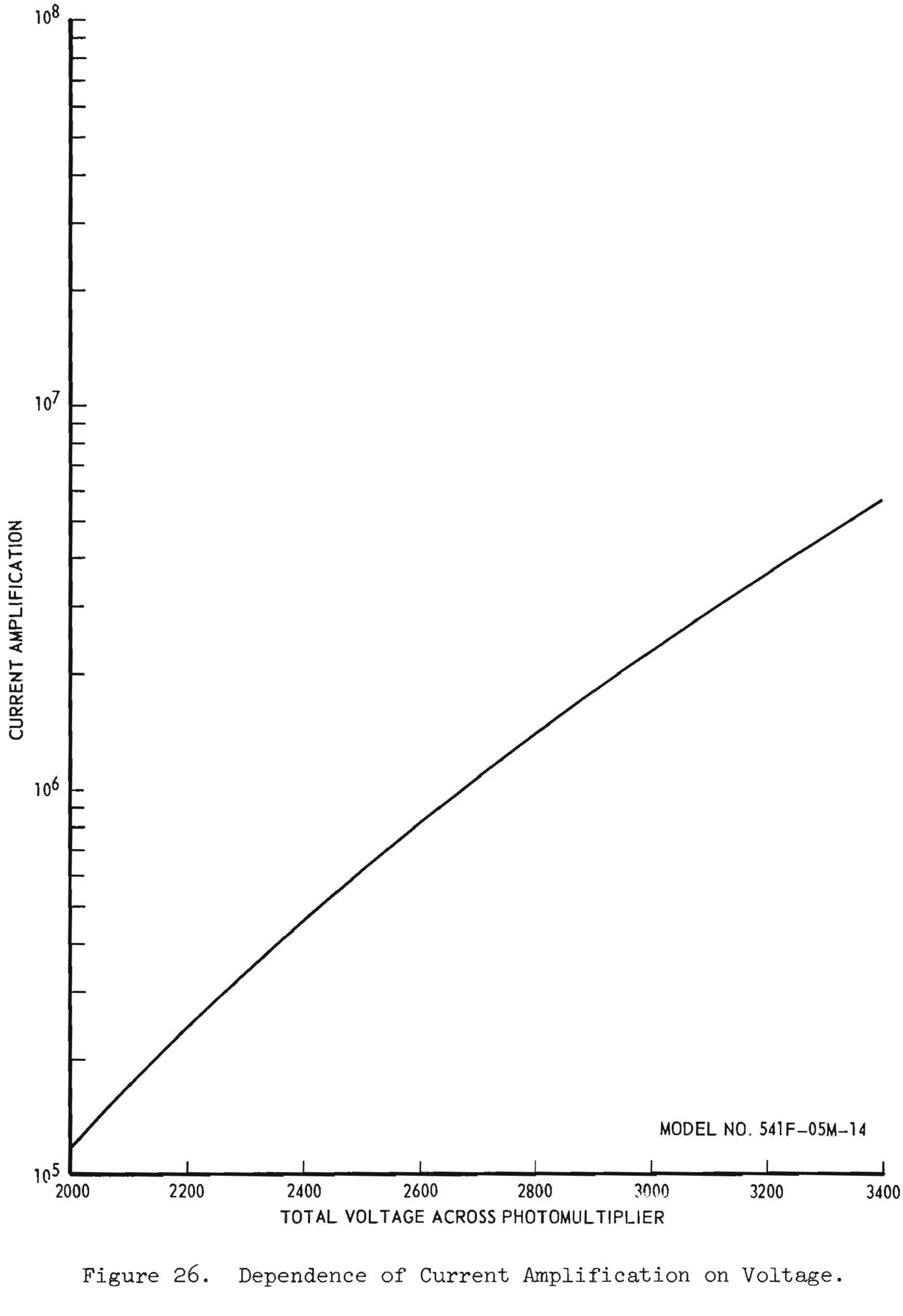

Figure 26. Dependence of Current Amplification on Voltage.

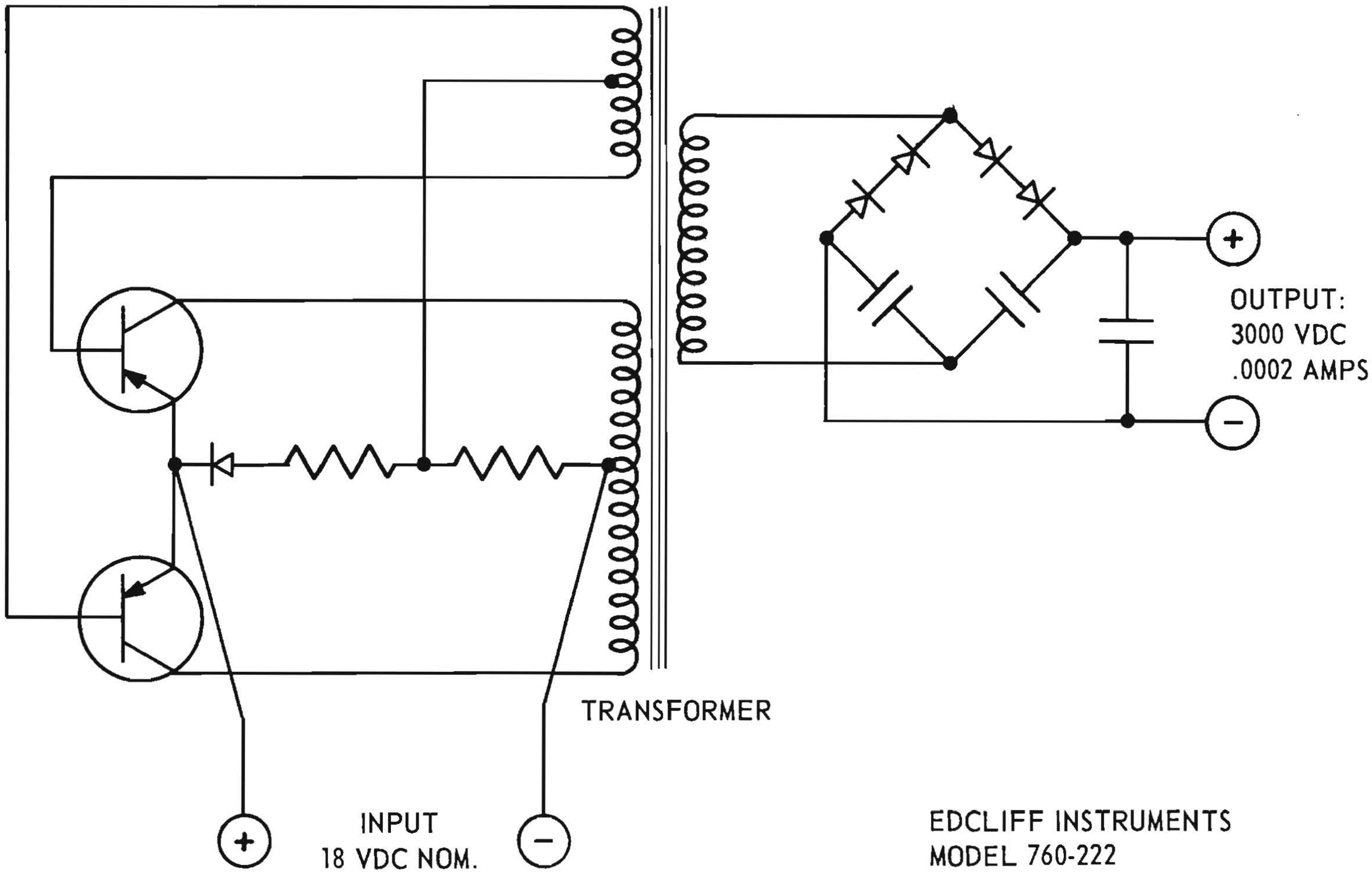

Figure 27. Schematic of DC-DC Converter.

Poor service from Edcliff Instruments on two occasions persuaded us to obtain the back-up DC to DC converter from another source. A Transformer Electronics Corporation Model 9567118 converter was bought at approximately a third of what Edcliff was asking for a comparable model. This unit has not been tested under field conditions, although the specifications are satisfactory.

Photomultiplier Tube Amplifiers

The amplifier circuit is shown in figure 28. The input stage is a 5886 subminiature electrometer tetrode V_1 connected as a triode. The plate load of V_1 is the base of Q_1 one of a pair of 2N1307 silicon PNP transistors having a common emitter load R_5. These two transistors have the bases of Q_3 and Q_4 as their collector loads. Q_3 and Q_4 are 2N336 silicon NPN types. The collector of Q_3 is direct coupled to the base of Q_5, another 2N336 operated as an emitter follower. The transistors Q_1, Q_2, Q_3 and Q_4 comprise a direct coupled differential amplifier that in large measure compensates for thermal drifts and changes in the supply voltage. The use of a vacuum tube followed by a PNP stage, which in turn is followed by a complementary NPN stage, permits direct coupling and an output of zero volts when the input is at zero volts without the use of voltage divider networks or Zener coupling diodes. The use of an emitter follower permits the use of a large collector load on Q_3 and hence a large voltage gain from this stage. Also, this voltage gain is independent of the output load. The output voltage is limited to +5 volts by the network R_6, R_{11} to protect the telemetry circuit. R_{10} protects Q_5 in the event of a momentary short circuit of the output wiring, and C_1 and R_{10} form a filter network that prevents feedback of high frequency signals into the amplifier

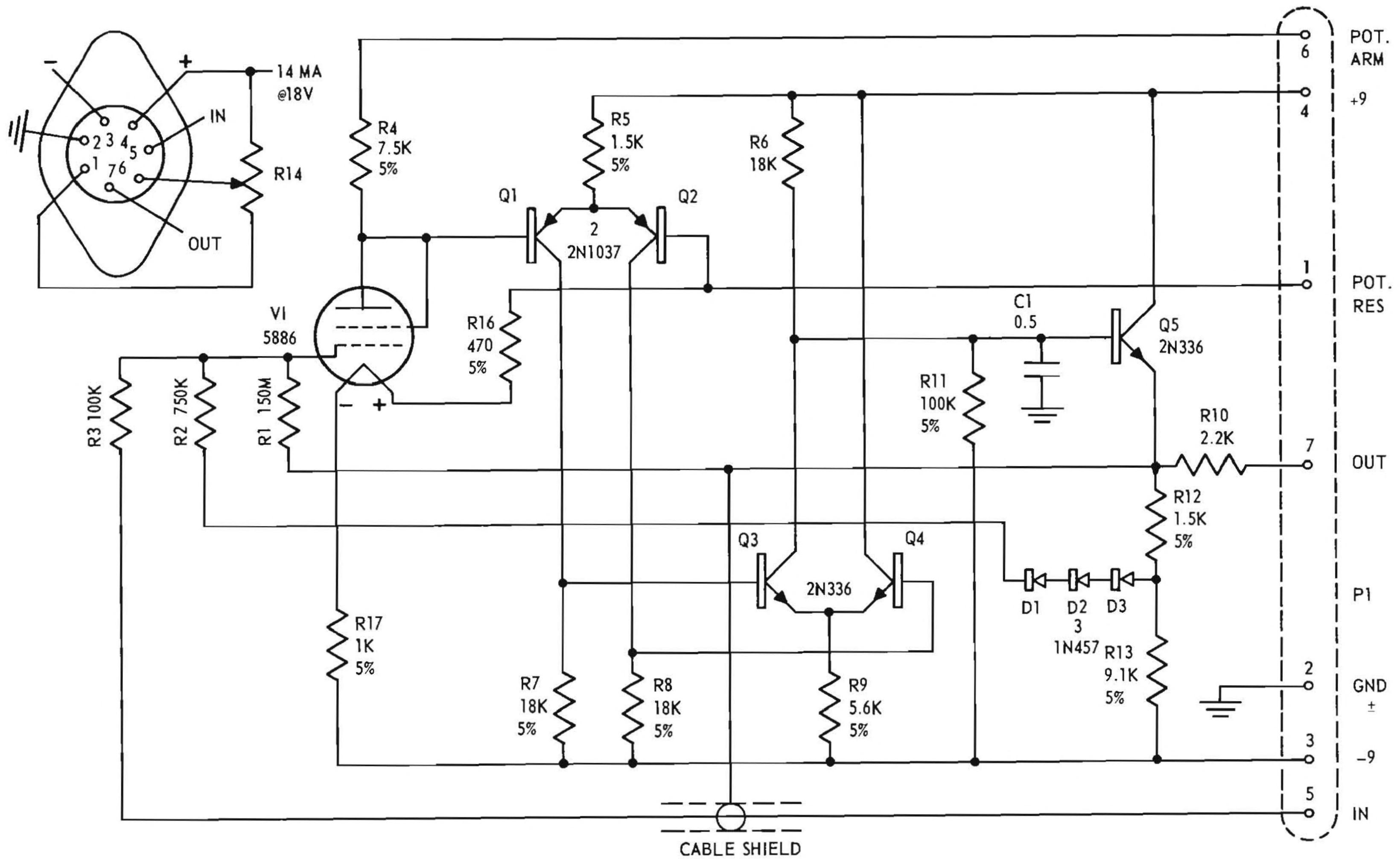

Figure 28. PM Tube Amplifier Schematic.

and limits the frequency response of the amplifier. Similarly R_3 prevents high frequency signals from reaching the grid of V_1. The voltage gain of the amplifier as a whole is about -3500, and the band width is limited to about 10 kc by capacitor C_1. Further band width limitation is accomplished by attaching the shield of a short length of shielded input cable to the output terminal. This limits the effective band width of the system to a little over 100 cps for the entire dynamic range.

Since the voltage gain of the amplifier is high and the grid current very small ($\sim 10^{-13}$ a) the output voltage will adjust itself so that the current through the feedback resistor R_1 is equal to the photomultiplier current I_m when the voltage at the input grid is very nearly zero. Then the output voltage $V_o = I_m R_1$. When $R_1 = 150$ meg. $I_m/V_o = 6.7 \times 10^{-9}$ amperes photocurrent per volt output. To increase the dynamic range of the amplifier, the 750 K resistor R_2 is automatically cut into the circuit when the output voltage reaches +2.5 volts by means of the biased silicon diodes D_1, D_2 and D_3. The effect of this network is to reduce the sensitivity by a factor of about 200 when the photocurrent exceeds 1.7×10^{-8} amps. A more elaborate circuit using a number of diodes and several cut-in points to give a quasi-logrithmic output might profitably be used; or feedback control of the photomultiplier supply voltage might be employed. However, the present circuit is simple and reliable.

In order to adjust for dark current a zero set control is provided for each amplifier. Most of the plate current of V_1 flows through the plate load resistor R_4. This resistor is returned to the top of the potentiometer R_{14} which is placed across part of the voltage divider that supplies filament power for V_1. Since the amplifier drift is < 10 mV/hour referred to the output, zero adjustment can be made several hours before a flight.

<u>Calibration Light</u>

A small "grain of wheat" lamp (Chicago #CM8-680) is used in conjunction with a constant current source to provide an optical calibration of the photomultiplier tubes. This is, of course, not an absolute calibration, but rather serves as a "ball park" figure; tolerances are not close enough to establish this circuit as an absolute calibration point. The calibration lamp serves to establish one point on the transfer characteristic of the photomultiplier-amplifier system, and the amplifier is calibrated by another means. Upon actuation of the calibration cycle microswitch by the grating cam, +28 volts is supplied to pin F of the MS3102C-18-1P connector on the detector head (see figure 29). This voltage is regulated to +12 volts by the 1N2976 Zener diode, which serves as primary power for the constant current source. The actual amount of current drawn by the lamp is variable with the adjustment of the 10 K potentiometer, and the current is adjusted so that an on scale reading is obtained for both photomultiplier tubes (approximately 50 ma). A Corning #7-54 filter is mounted so that the light from the calibration lamp that enters the detectors head (see figures 18 and 29 for positioning of the calibration lamp and circuitry) is predominantly in the ultraviolet region. The circuit will hold a constant current within 1% for a 10% variation in both input voltage and output load. More elaborate constant current generators could be used in conjunction with more stable lamps to provide an accurate calibration source, but the present system is simple and serves its purpose.

Thermistors

Two thermistors are incorporated in the detector head to measure temperature. One, mounted on the photomultiplier tube amplifier oven, measures its temperature and provides an indication of the operation of the thermostats for maintaining the amplifiers at a constant temperature. The other, mounted on the middle plate, (see figure 18) gives a rough approximation as to the temperature of the other components in the detector head. Each thermistor is a Veco #21W5, which has a nominal resistance at 25° C of 100 ohms. For the TM signal, voltage is developed across the thermistor and a 180 ohm resistor in series (see figure 29) which in turn is in series with a 4700 ohm resistor and is fed from a Zener regulated (1N3029) 24 volt supply.

Amplifier Oven

The two photomultiplier tube amplifiers are enclosed in a thermostatically controlled oven so as to maintain a constant temperature for the nonlinear feedback element (the 150 megohm resistor and the 750 K resistor in series with the 3 silicon diodes). The outside temperature of these ovens is nominally +85° F ± 3° F, and the resultant stability of the amplifiers is quite good. The temperature is maintained by a Fenwal #32000-1 thermostat, and an identical thermostat, although set to a higher cut-off temperature, is in series with the first one in the event the first thermostat malfunctions.

A telemetry signal formed by the 1N457 diode and the 261 K resistor in series and the 10 K ohm resistor for load provides an indication when the heater is on. Also multiplexed with this signal is a voltage derived from a 1N457 diode and a 560 K resistor which indicates when power is

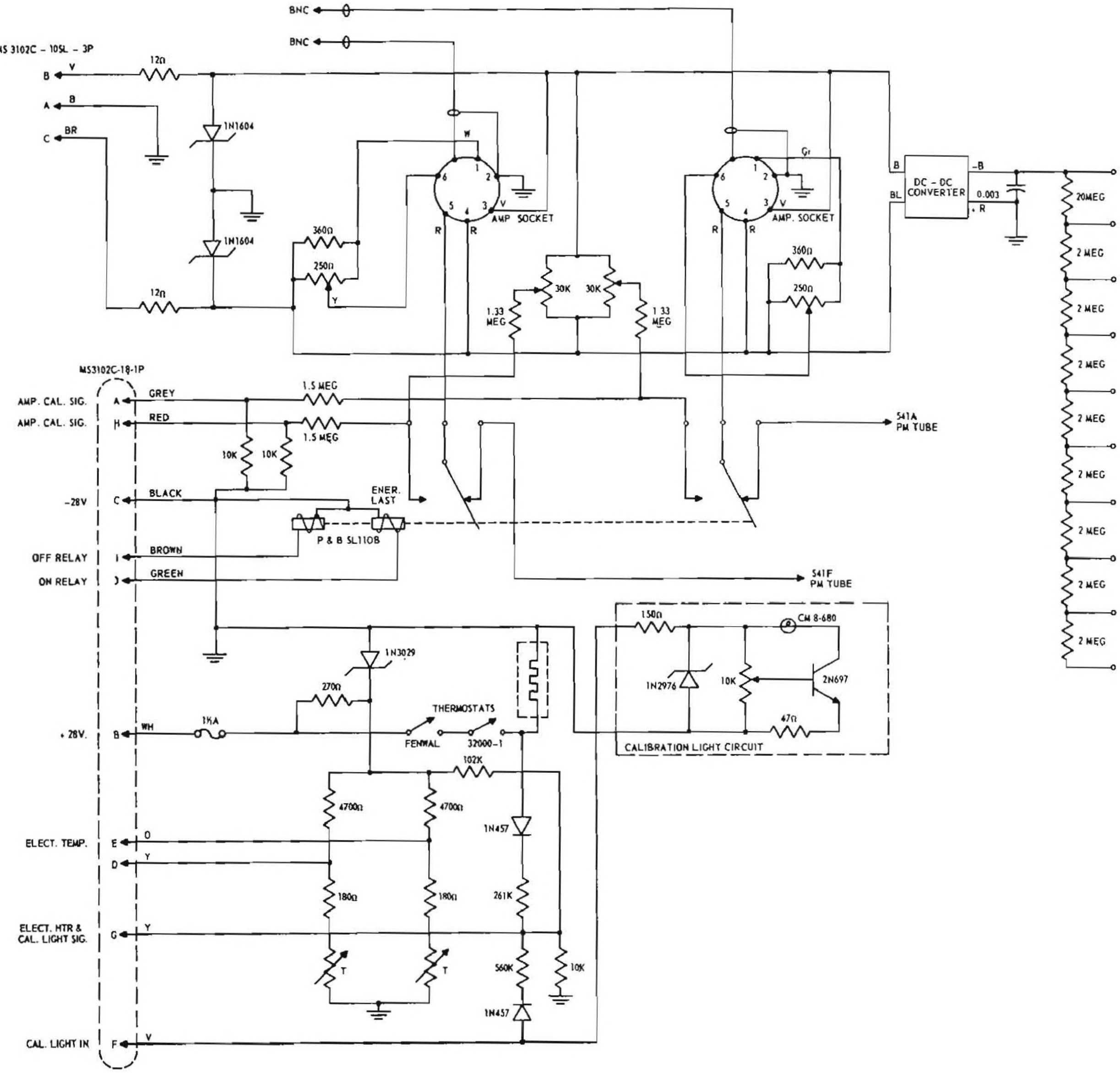

Figure 29. Detector Head Schematic.

supplied to the calibration lamp. A resting bias of approximately 2.1 volts is developed by the 102 K resistor. The output voltage determines the state of the two functions as follows:

2.1 volts	calibration lamp off, heater off
2.8	calibration lamp on, heater off
3.3	calibration lamp off, heater on
3.7	calibration lamp on, heater on

Thus, by determining the voltage from the commutator channel, it is possible to determine the state of the electronics heater and the calibration lamp.

Control Box

The control box, which is mounted on the gondola next to the pointing control amplifiers, provides a means of controlling the power to the spectrometer and pointing control as well as a junction box for power connections and telemetry signals. Three main functions are provided during flight by the control box; namely: turn on-turn off sequencing, power distribution, and telemetry commutation. In addition, for testing purposes, this box also provides connection for all telemetry inputs and each of the twenty-eight inputs to the commutator for ground monitoring. The circuit diagram for this control box is shown in figure 30.

The flight package has the ability to be turned on and off via a radio command from the ground generated by the personnel at AFCRL Balloon Branch. For the purposes of explanation, assume that the spectrometer and associated equipment are all on. The first time an external switch is closed (by radio command) or the switch is activated on the control box, the pointing control and the Ferguson drive motor are turned off, and all pointing control clutches are activated so that the spectrometer is held

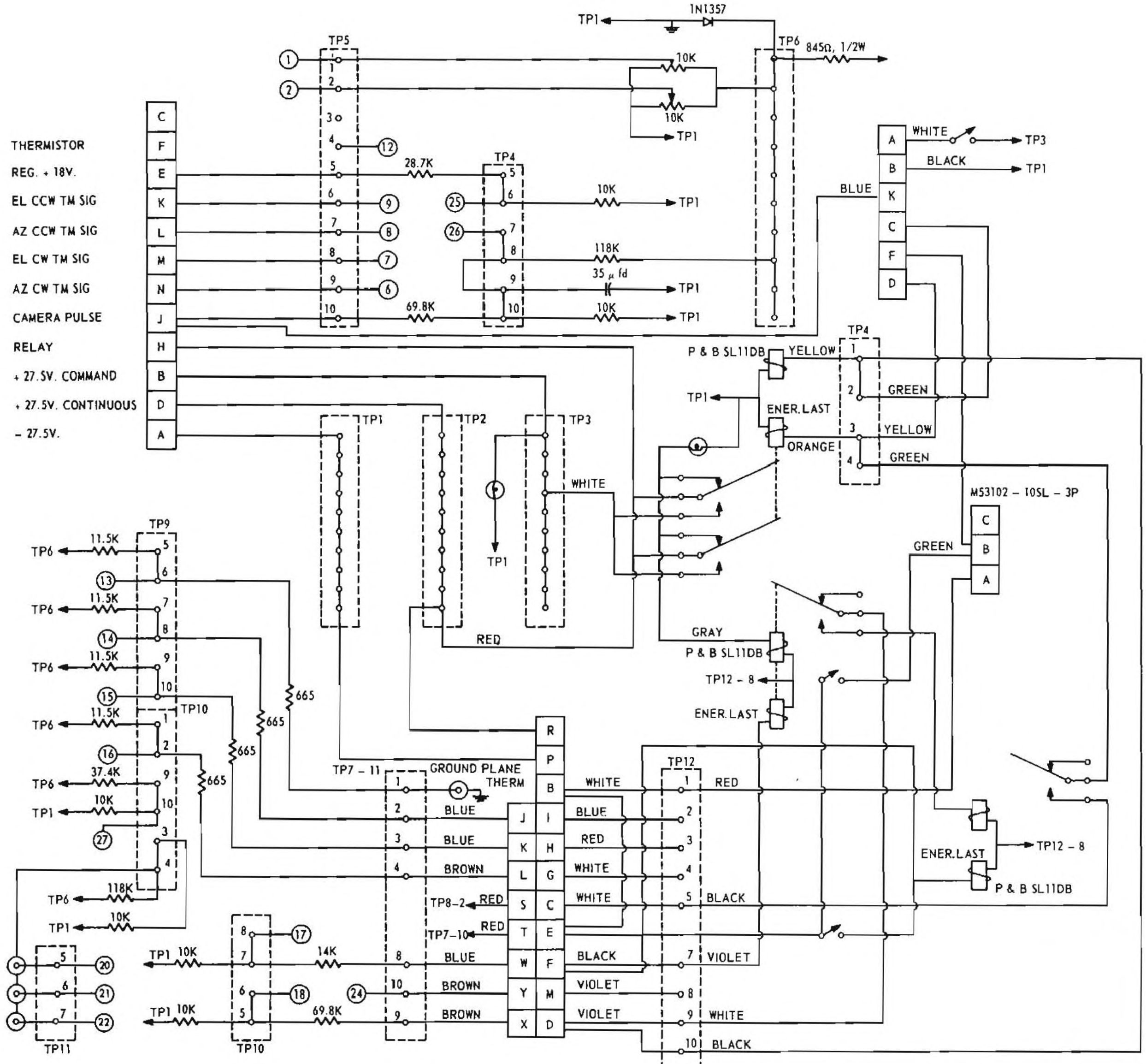

Figure 30. Control Panel. Page 1 of 2.

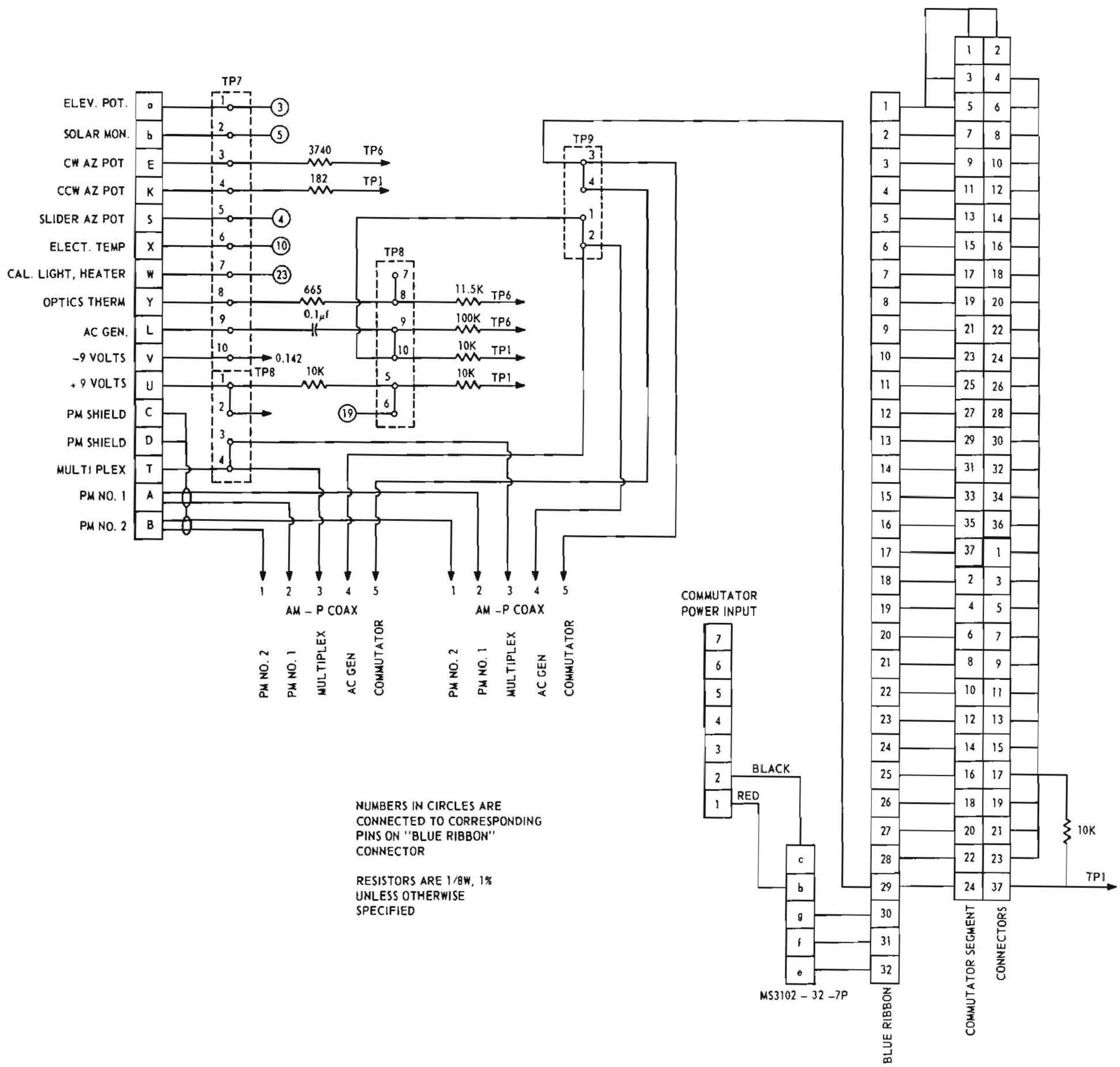

Figure 30. Control Panel. Page 2 of 2.

in a rigid position. The next switch closure turns the pointing control and the Ferguson drive motor back on and releases the clutches. The next switch closure turns off all power to the spectrometer, pointing control and associated equipment except telemetry (this was to be controlled by another command channel), and on the fourth switch closure all of the spectrometer and associated equipment is turned back on and from there the cycle can repeat itself.

Power from the 28 volt main battery pack and the 24 volt electronics battery pack come into the control box to be distributed to the various electronic packages. These two voltages in addition to the TM battery voltage are suitably reduced through voltage dividing networks to serve as input to the commutator. The 28 volt supply also delivers through suitable circuitry the Zener regulated voltage for the thermistors; although a non temperature compensated Zener was used in the 1 July 65 flight, it is strongly recommended that a temperature compensated reference element be used to regulate this voltage in the future.

The commutator and associated circuitry is also contained in the control box. If an input signal is not in the range 1.0 to 5.0 volts, suitable circuitry is incorporated to put the input into this range, e.g. a thermistor signal strictly is a change in resistance, therefore, a voltage divider is necessary to produce a voltage which is dependent upon the temperature of the thermistor. The power to drive the commutator (6.0 volts) is obtained from a tap on the main battery and the value of this voltage is somewhat critical. The motor that drives the commutator is not governed, and therefore, the speed is dependent upon the input voltage. For decommutation, the speed has to be within 10% of the IRIG speed in order to obtain the various signals, and thus (approximately) the input voltage has to be within 10% of 6.0 volts.

The five inputs to the telemetry subcarrier oscillators are available at two AM-P multiple coax connecters, one of which is to monitor the TM signals while on the ground, and the other is for the TM system.

A list of the connectors and their pin designations is shown in Table II.

American Pamcor taper pin blocks and pins are used to somewhat simplify the wiring. In the control box 12 blocks (10 stations per block) are used for the majority of connections. Three taper pin blocks (designated TP1, TP2, and TP3) are all common connections and are used for -27.5 volts (ground), +27.5 volts continuous, and +27.5 volts on by command respectively. In addition, an all-common block, TP6, is 18 volts regulated for the thermistors and other telemetry signal sources. The remainder of the taper pin blocks serve as junctions or tie points. The resistors used throughout are IRC CE series, which are a 1% tolerance metal film type with an excellent temperature and voltage coefficient.

In addition to the connectors listed in Table II, four Amphenol subminax coax connectors are mounted on the side of the control box. One of these coax connections is for the ground plane thermistor and has its outer shield grounded. The other three coax connectors are for the solar position sensors and have their outer shield floating 1.0 volts above ground. A toggle switch is also included on the front panel of the control box for the purpose of controlling power to the intervalometer.

Intervalometer Box

Another box which is mounted on the gondola and is designated as the

Table II

PIN DESIGNATIONS OF CONNECTORS FROM CONTROL BOX

Spectrometer connector (Amphenol 165-27)

A	Photomultiplier #1
B	Photomultiplier #2
C	Shield return for photomultiplier
D	Shield return for photomultiplier
E	CW terminal of azimuth position potentiometer
K	CWW terminal os azimuth position potentiometer
L	Reference AC generator
S	Slider terminal of azimuth position potentiometer
T	Grating switch - guard cell multiplex
U	+24 volts for detector head
V	-24 volts for detector head
W	Calibration light, heater multiplex signal
X	Electronics temperature thermistor
Y	Optics temperature thermistor
a	Elevation scan potentiometer
b	Solar monitor signal

Pointing control connector (Amphenol 165-11)

A	-27.5 volts (ground)
B	+27.5 volts on by command
D	+27.5 volts on continuously
E	Regulated +18 volts
F	Pointing control temperature signal
H	Clutch relay
J	Camera pulse voltage
K	Elevation CCW TM signal
L	Elevation CW TM signal
M	Azimuth CCW TM signal
N	Azimuth CW TM signal

Intervalometer connector (Amphenol 165-16)

A	+27.5 volts
B	-27.5 volts
C	On relay
D	Off relay
F	Impulse relay coil
K	Camera pulse voltage

Remote turn on-turn off connector (MS3102-10SL-3P)

A, C	External switch closure

Table II Cont.

Main power connecter (MS3102-32-7P)

C	External relay coil
D	Internal relay coil
E	Internal-external relay armature
F	Internal-external relay contact (external)
J	Main battery thermistor
K	TM battery thermistor
L	Detector head electronics battery thermistor
P	-27.5 volts in
R	+27.5 volts in
S	+24 volts (for detector head)
T	-24 volts (for detector head)
W	TM battery voltage
X	Main battery voltage
Y	Battery heater signal
b	+6 volts in (for commutator)
e	Ground for commutator

intervalometer box, although the name is a slight misnomer, has two primary functions: (1) to contain the impulse relay (P and B type AP, hermetically sealed) which is used in the remote turn-on-turn-off system, and (2) house the intervalometer which supplies +27.5 volts to the camera for $\frac{1}{4}$ second every 120 seconds. A third function was anticipated for this box and that was the housing of the double aneroid switch and the circuitry for the impact switches, but this was changed about a month prior to the flight. The circuit diagram is shown in figure 31. The 1N2070 diode across the coil is to prevent a high voltage spike from appearing on the lead when the coil has been deenergized. The intervalometer is a motor driven timer which has functioned well on both flights without any problems except possibly a slight retardation of the motor speed.

Junction Boxes

Two wiring junction boxes are mounted on the yoke assembly and two more junction boxes are mounted on the spectrometer mount, and the wiring diagram for these boxes is shown in figures 32, 33, 34, and 35. Junction box #1, mounted on the yoke, is mainly a distribution box for power. The reversing relay for the stepping motor (Ferguson drive) is also included as well as the voltage dividing network for the elevation scan potentiometer. The pointing control error signals pass adjacent to this junction box and go to the Amphenol 165-26 connector. A toggle switch is mounted on the junction box which turns off the stepping motor when desired (for example, during the calibration procedure where it is desirable to have everything running and yet have the spectrometer stationary.)

Junction box #2 is mainly the calibration circuitry for the PM tube amplifiers. Taper pin block #1 (TP1 on the diagram) is a junction point

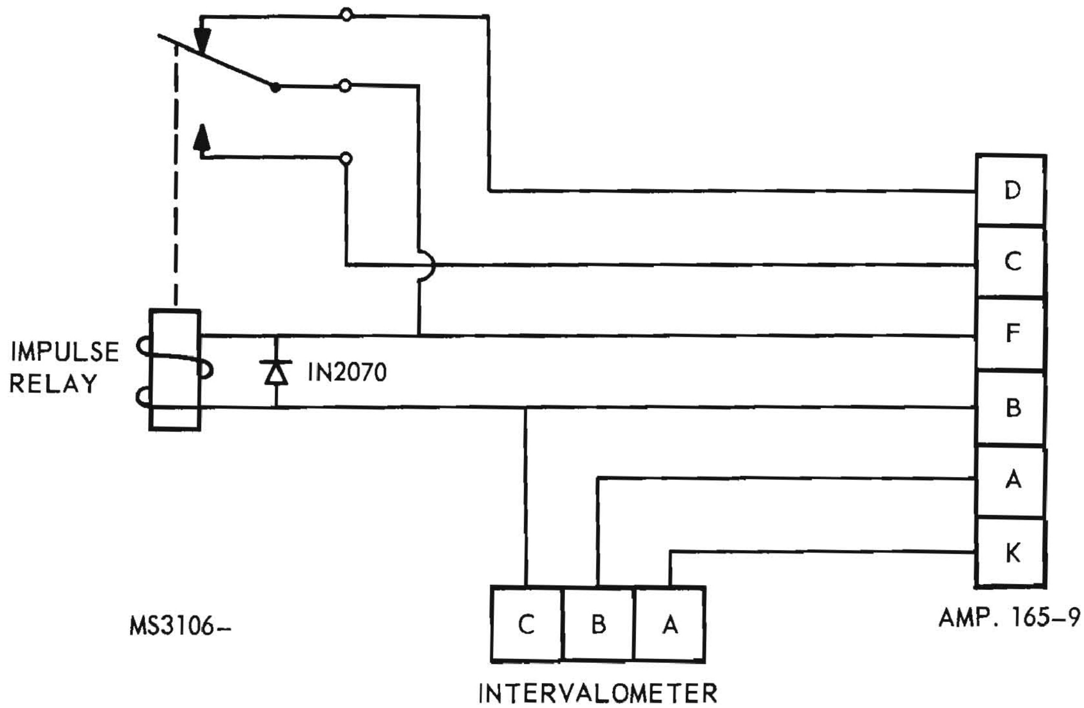

Figure 31. Intervalometer Box Schematic.

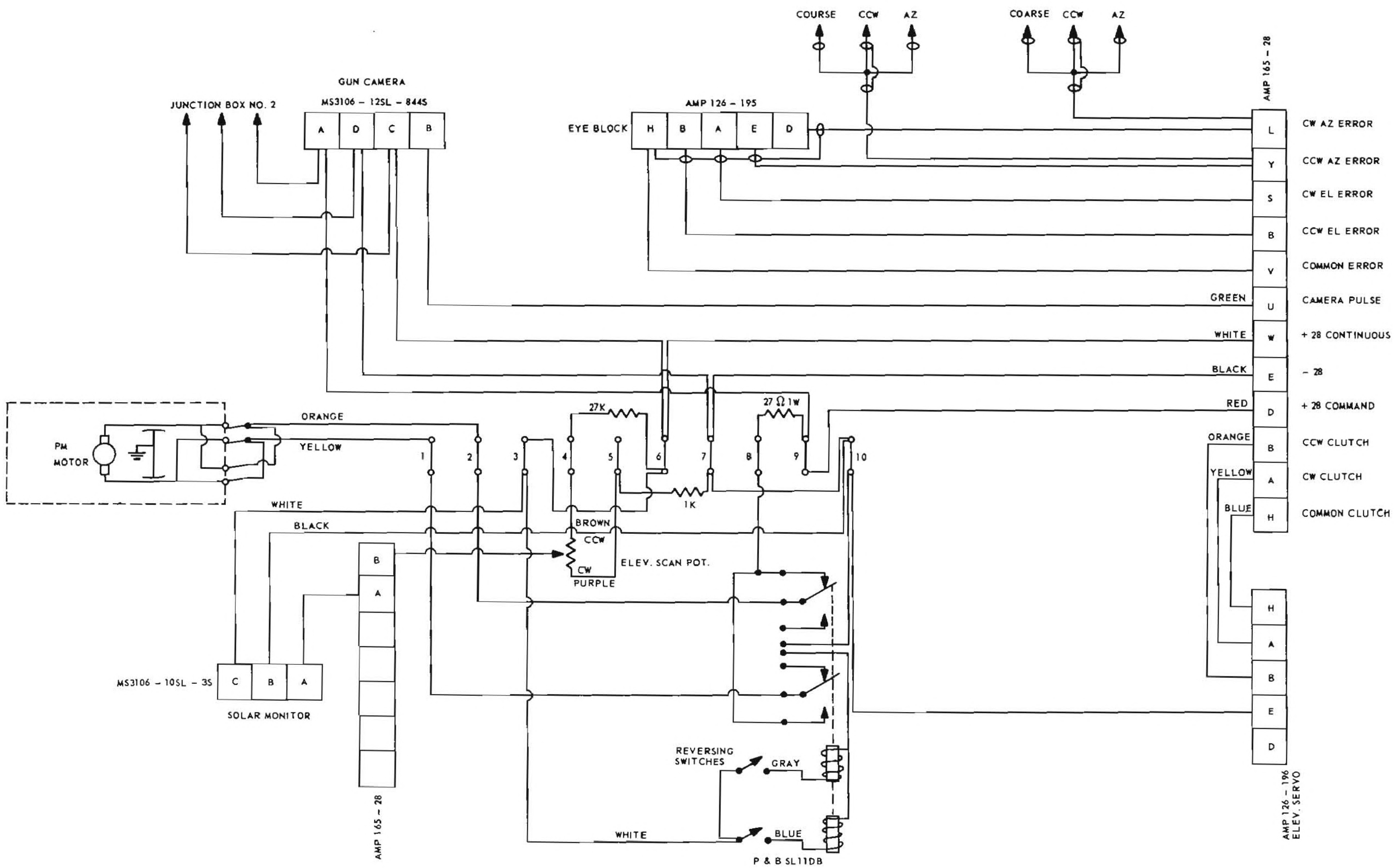

Figure 32. Junction Box #1.

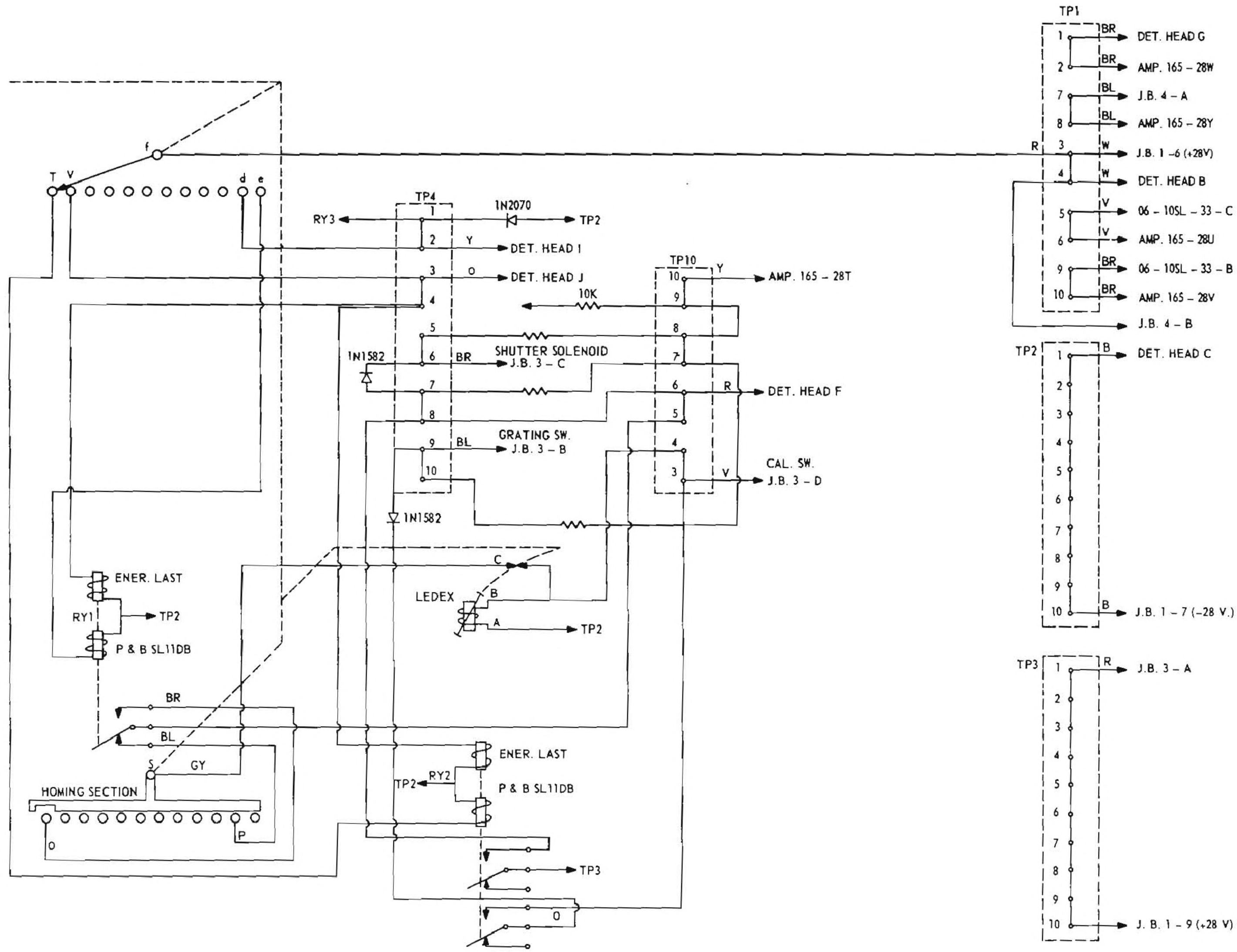

Figure 33. Junction Box #2. Page 1 of 2.

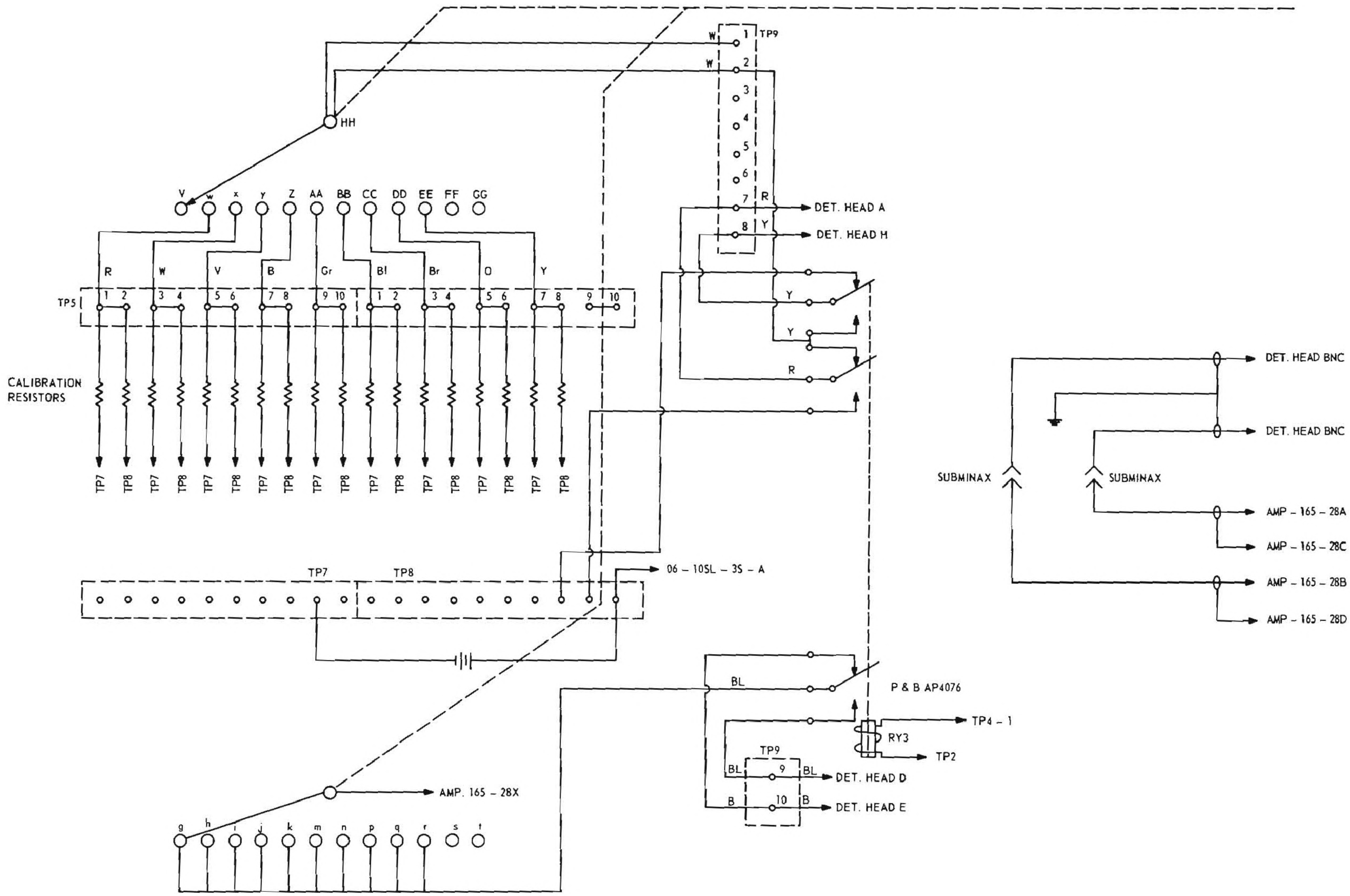

Figure 33. Junction Box #2. Page 2 of 2.

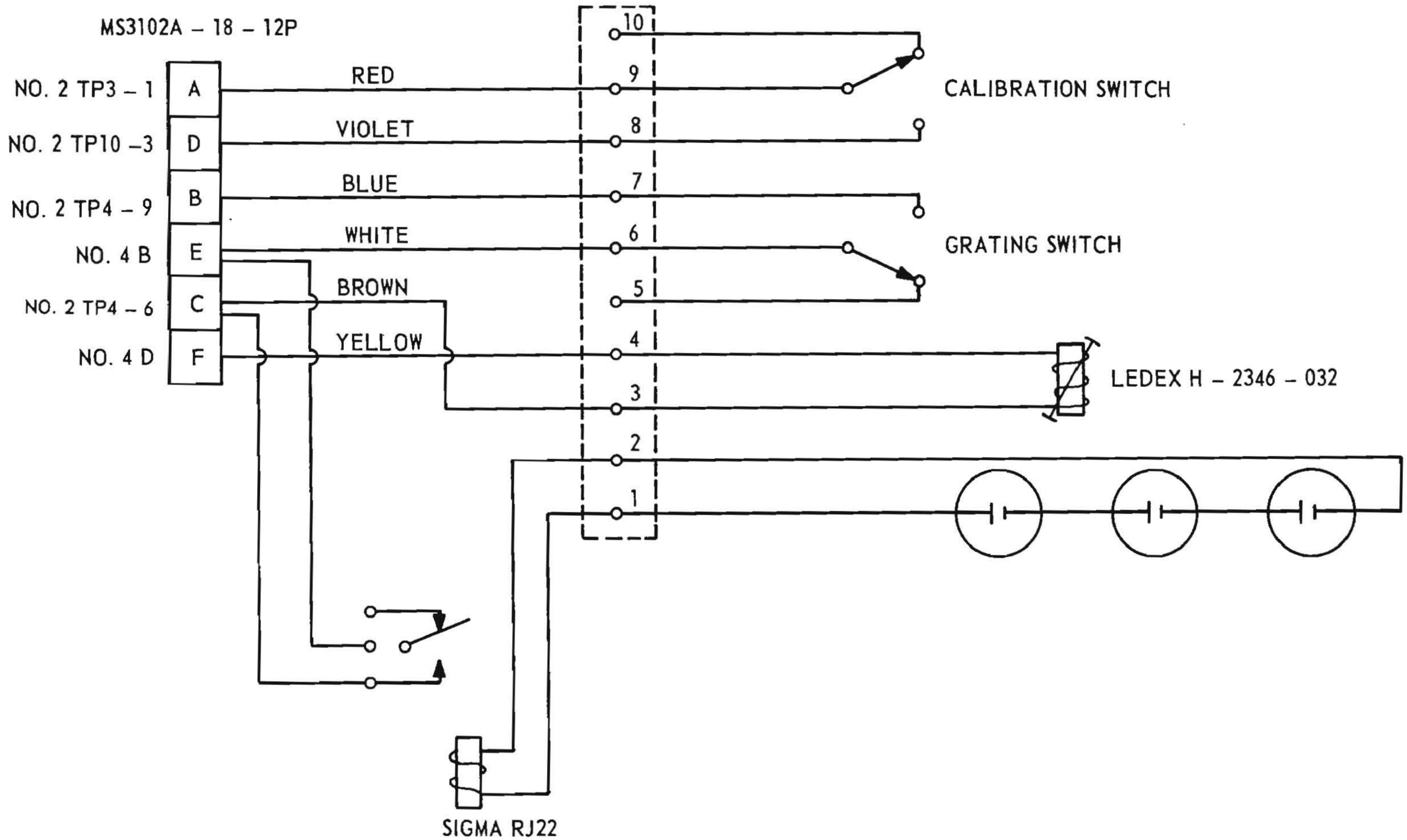

Figure 34. Junction Box #3.

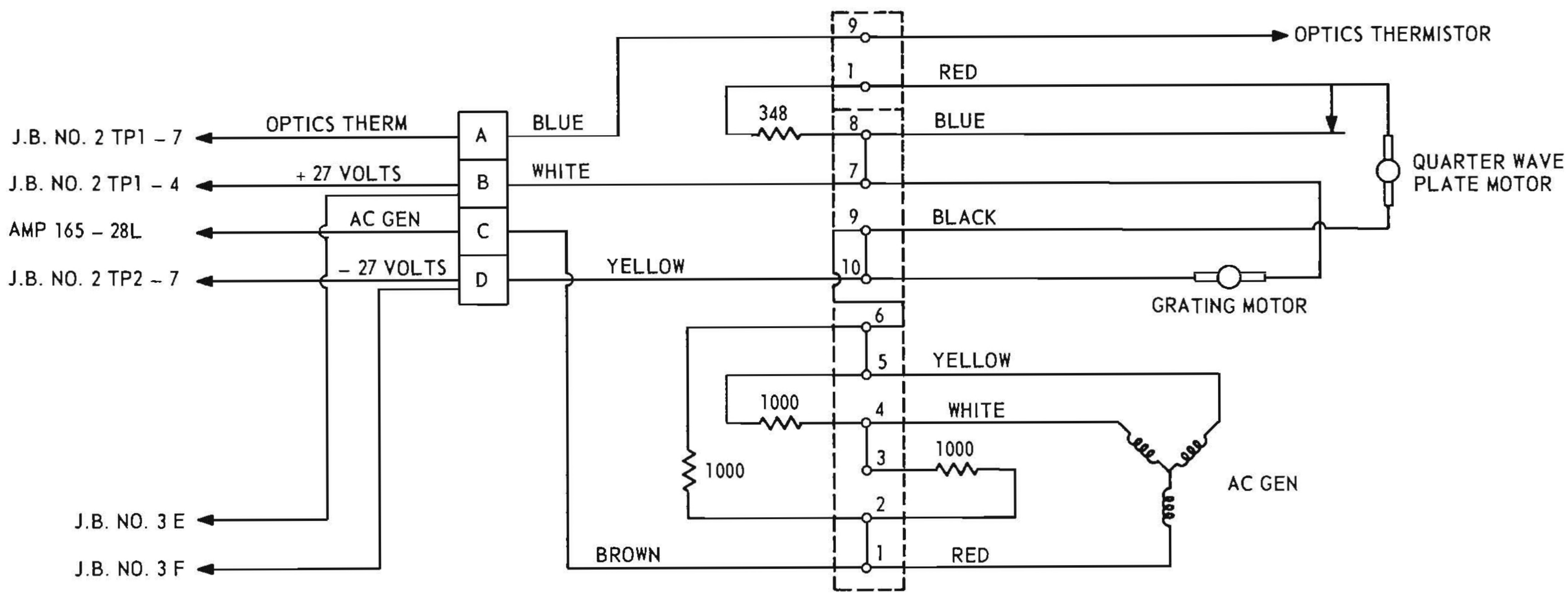

Figure 35. Junction Box #4.

for various signals coming from the spectrometer and going to the Amphenol 165-28 connector. TP2 is -27.5 volts (ground) and TP3 is +27.5 volts which is on by command. For a functional description of the calibration sequence, consider the following (refer to figure 33 and 34):

A microswitch actuated by the grating cam (called the calibration switch) delivers +27.5 volts to TP10-3, causing the Ledex rotary stepping switch to advance one position to position 2. In this position of the Ledex switch, through contact U, RY1 and RY2 plus the latching relay in the detector head are all energized. RY1 actuates the automatic homing section of the Ledex switch to home on position 11 through pin P. RY2 turns on the calibration light in the detector head through TP10-6, actuates the shutter solenoid (to reduce the light passing through the spectrometer) through TP4-7 and the 1N582 diode to J.B.3-C. The latching relay in the detector head disconnects the PM tubes from the amplifiers and connects the input of the amplifiers to the calibration circuit through TP9-7 and TP9-8. While the Ledex switch is homing on position 11, voltages are fed into one PM tube amplifier as selected by RY3 through contact HH and RY3. (The voltages are determined by the voltage dividing network whose values are adjusted after assembly of the instrument). The battery which supplies this negative polarity signal (with respect to ground) is a 10 volt mercury battery. In position 11, the latching relay in the detector head is reversed (reconnecting the photomultiplier tubes) and the impulse relay (RY3) is actuated through contact d of the Ledex. It stays in this state until the calibration switch is again activated. This state is one in which the PM tubes are connected to the amplifiers, the calibration light is on, and the shutter solenoid is activated.

When the calibration switch is activated again, the Ledex again steps one position, RY1 is reversed causing the Ledex to home on position 1 through pin D. In position 1, the calibration light is turned off and the shutter solenoid is released through RY2, which is activated through pin T of the Ledex.

If for any reason, the calibration switch only gives one switch closure during the calibration time, the RY2 would be energized at the end of the normal calibration time. The grating switch, acting through TP4-9 and the 1N1582 diode would then be capable of resetting the calibration circuit to normal operation. RY3, besides selecting the amplifier to be calibrated, also switches the two thermistors which are located in different parts of the detector head into a commutator channel through pin X of the Amphenol connector.

Junction box #3 contains the guard cell relay (Sigma # 22RJ 1000) and associated circuitry. Also in this box are the switch leads from the calibration and grating switches. For the guard cell, the three silicon photocells (IRC S1020E) wired in series are mounted in a bracket (see figure 14) so that when the spectrometer is pointing within 30° of the sun, sufficient current is produced by the cells to close the relay, which activates the Ledex rotary solenoid (# H-2346-032) that pulls the auxiliary slit assembly or "shutter" over the entrance slit of the spectrometer. When one of the photocells is shaded by the mounting bracket, its resistance increases to the point where the current that flows through the circuit is insufficient to close or hold closed the relay so the rotary solenoid is deenergized.

Junction box #4 is mainly a power distribution box which supplies power to the quarter wave plate motor and the grating drive motor. (A word of caution: the grating drive motor requires reversed polarity in order to drive in the right direction so as not to foul the switch cams.) Also contained in this box is the load resistors for the 3-phase AC generator, and the reference generator and optics thermistor signals are brought out to pins A and C respectively on the MS3102 connector.

Cabling Diagrams

The interconnections between the various components of the system are shown in figures 36, 37, and 38, which are the pointing control amplifier case, the spectrometer and yoke assembly, and the gondola and spider assembly, respectively.

Pointing Control

The reference axis from which all measurements are made is determined by the bi-axial pointing control, originally built by Hi-Altitude Instrument Company*. This is basically an electro-optical-mechanical system which seeks the brightest object in the sky and rotates the spectrometer with respect to the gondola. The system is a null type feedback system, the feedback being the mechanical rotation of the spectrometer which attempts to equalize the amount of light falling upon two opposing sensors. Drive for the rotation of each axis is provided by a PM motor (Barber-Coleman FYLM 73340-3) which runs continuously and two hysteresis type clutches which provide the differential torque which is required.

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*Hi-Altitude Instrument Company, 1560 S. Otus Street, Denver, Colorado 80226, (303)-922-2712, Mr. Al Goddard.

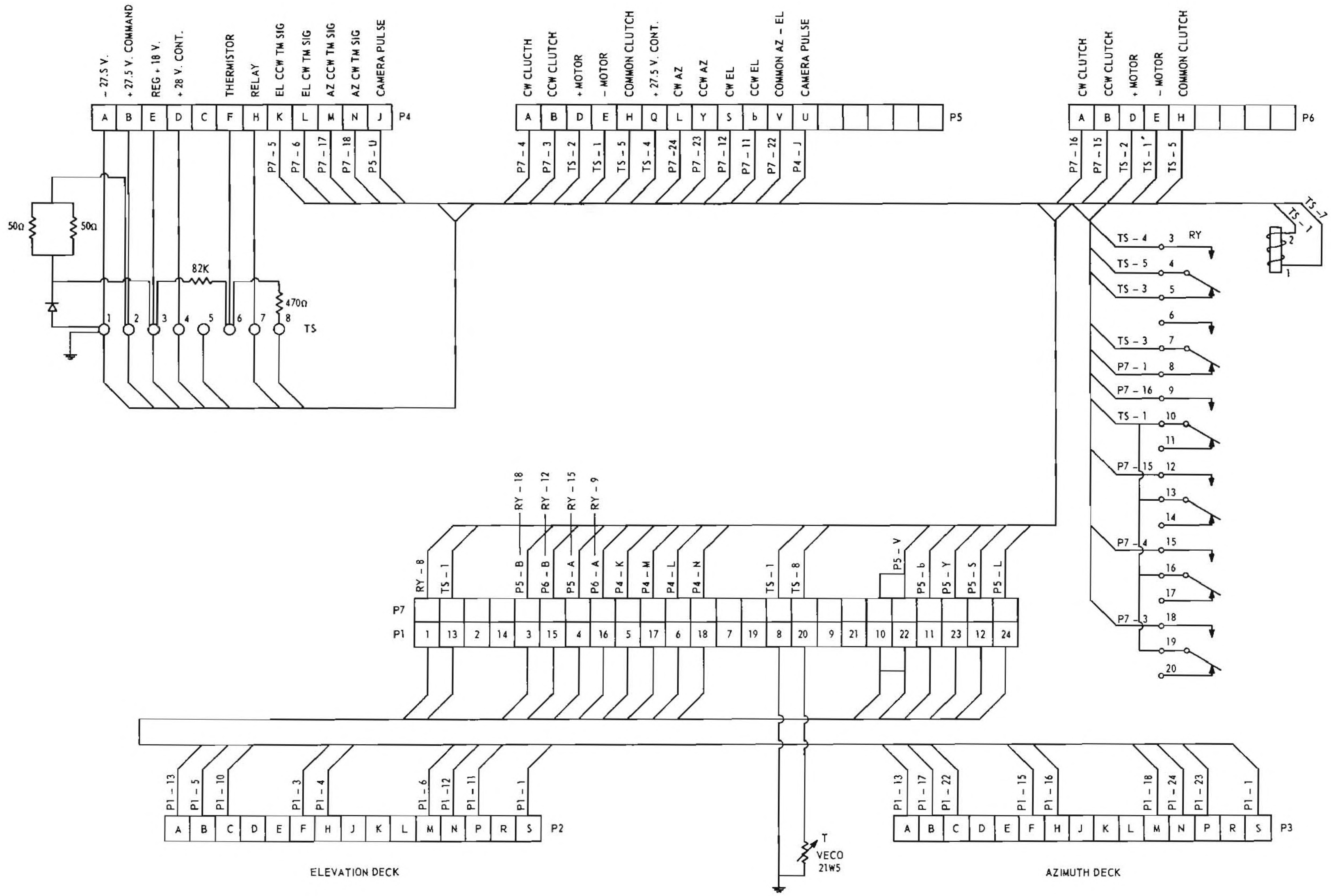

Figure 36. Cabling Diagram PC Amplifier.

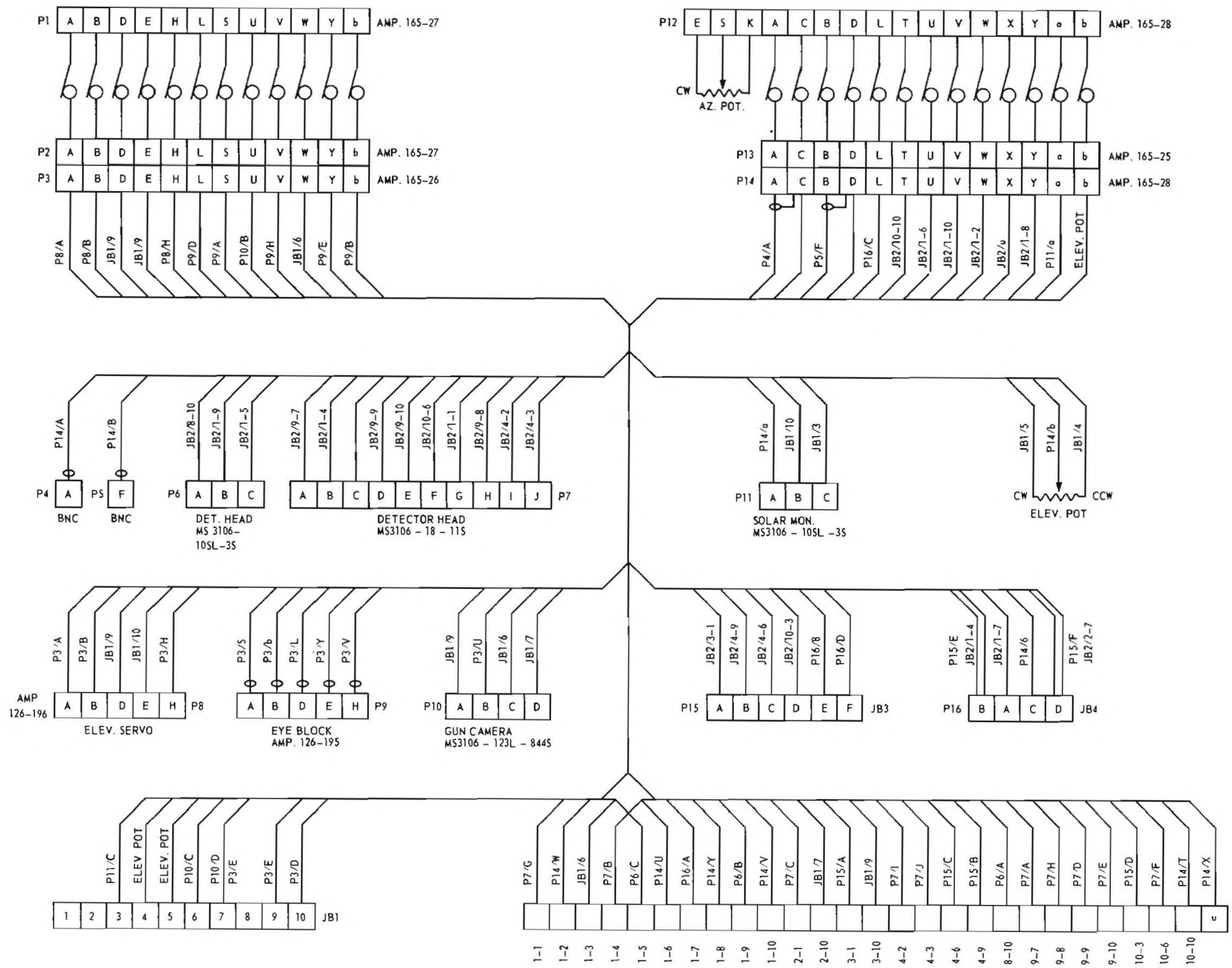

Figure 37. Cabling Diagram Yoke and Spectrometer.

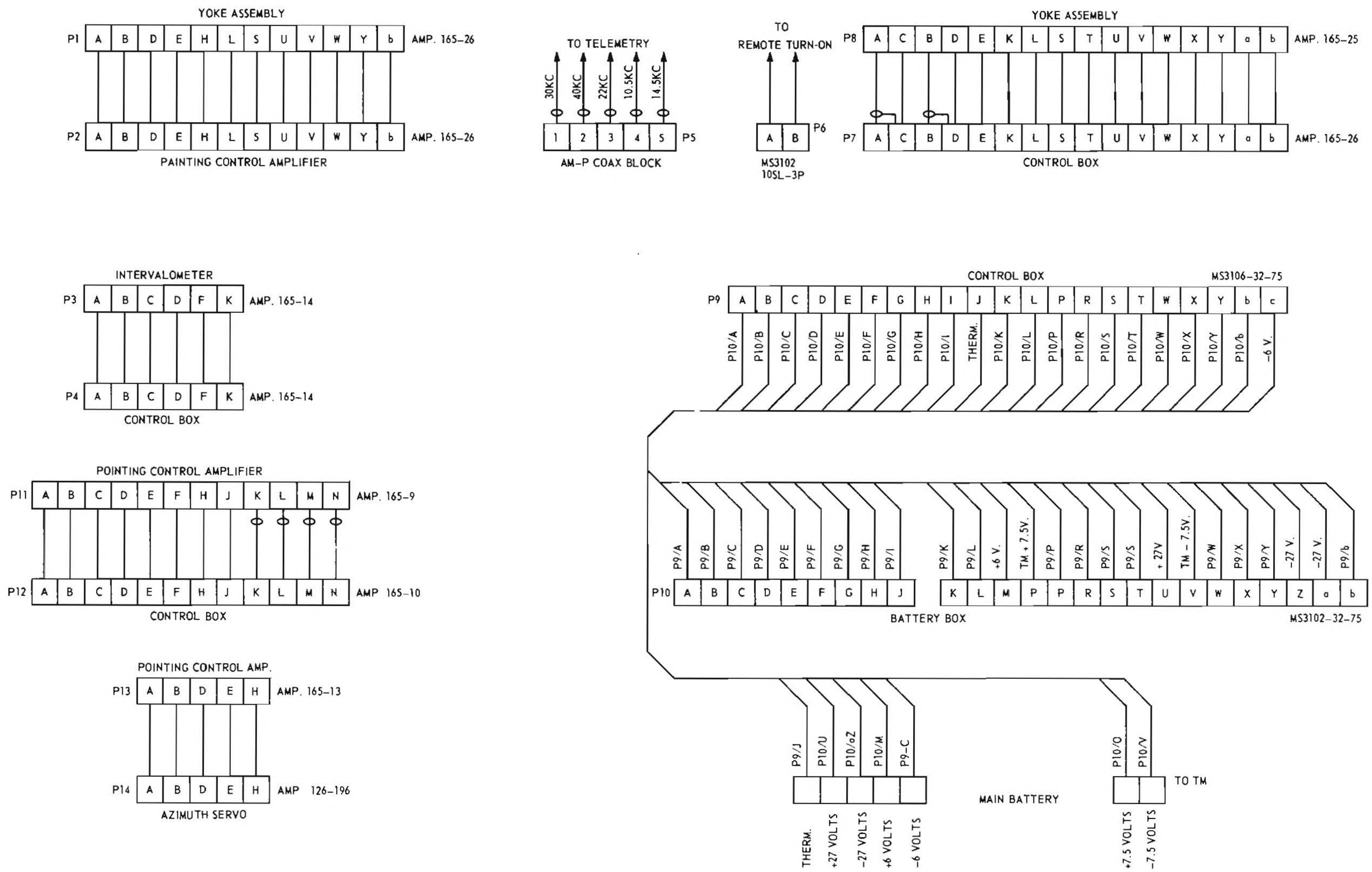

Figure 38. Gondola Cabling Diagram.

On the 26 August 1964 flight, the pointing control seemed to fail during ascent, but it did start working again after float altitude had been obtained. On this basis, the electronic portion of the system was completely reworked, although the mechanical and optical systems remained essentially intact. The redesign of the amplifier eliminated many electronic components and permitted a reduction in the size of the amplifier case and a slightly easier task of rewiring. The system produced error signals throughout the flight of 1 July 1965, but the entanglement of the flag line prevented the rotation of the spectrometer.

Error Sensors

For each axis two sets of error sensors are utilized. One set, commonly referred to as the coarse sensors, have a wide field of view (either approximately 60° or 45° depending upon the rotation of a sensor hood) and are placed around the spectrometer yoke so that they "see" approximately 360° in azimuth and 90° in elevation. These coarse sensors have a 301 ohm resistor in series with their output so that the signal is decreased by a factor of 10 (load for the sensors is 30.1 ohms). If the spectrometer were far removed from the sun in either azimuth or elevation, the coarse sensors would produce sufficient error signal to cause the spectrometer to rotate in the proper direction so that the fine eye block could eventually produce error signals that would accurately position the spectrometer. The coarse sensors have an opal glass diffusing disk in front of a silicon photocell which has been imbedded in Scotchcast #2 resin. The hardened resin is faced in a lathe to bring the photocell close to the surface.

The fine eyes or sensors have a field of view of approximately 5°

and are slightly different from the coarse sensors. A small infrared transmitting filter is placed in front of a small meniscus lens which focuses on a knife edge. This lens is mounted in an eccentric so that the image of the sun can be focused on the knife edge. It is possible by adjusting the eccentrics for the two opposing sensors to have the sun exactly split by the knife edges, i.e., one sensor would see exactly one half of the sun simultaneously while the other sensor would see the other half. This arrangement is supposed to be capable of positioning the spectrometer to within $\frac{1}{2}^{\circ}$; i.e. the sun's diameter.

Shielded wire (RG-188/U) connects the sensors with the slip rings and eventually the pointing control amplifier, which is mounted on the gondola frame. Power for the elevation clutches also passes through the slip rings, but the azimuth servo is mounted on the frame so that slip rings are not required. The use of shielded cable and the relative low impedance of the input circuit seems to be sufficient protection against RF interference from the telemetry system, a problem which was present on the first flight.

<u>Circuit Description</u>:

The Hoffman 110C silicon solar cell sensors are connected between points N and C and between P and C shown on the amplifier schematic (figures 39 and 40). The optomechanical arrangement of the sensors is such that a differential signal is developed between points N and P whenever the sensors are not pointed directly at the sun. The 30.1 ohm resistors provide a fixed resistive load across the sensors, and were chosen so that the sensor output voltage would be linearly related to the illumination on the sensor. This arrangement also prevents the possibility of reverse

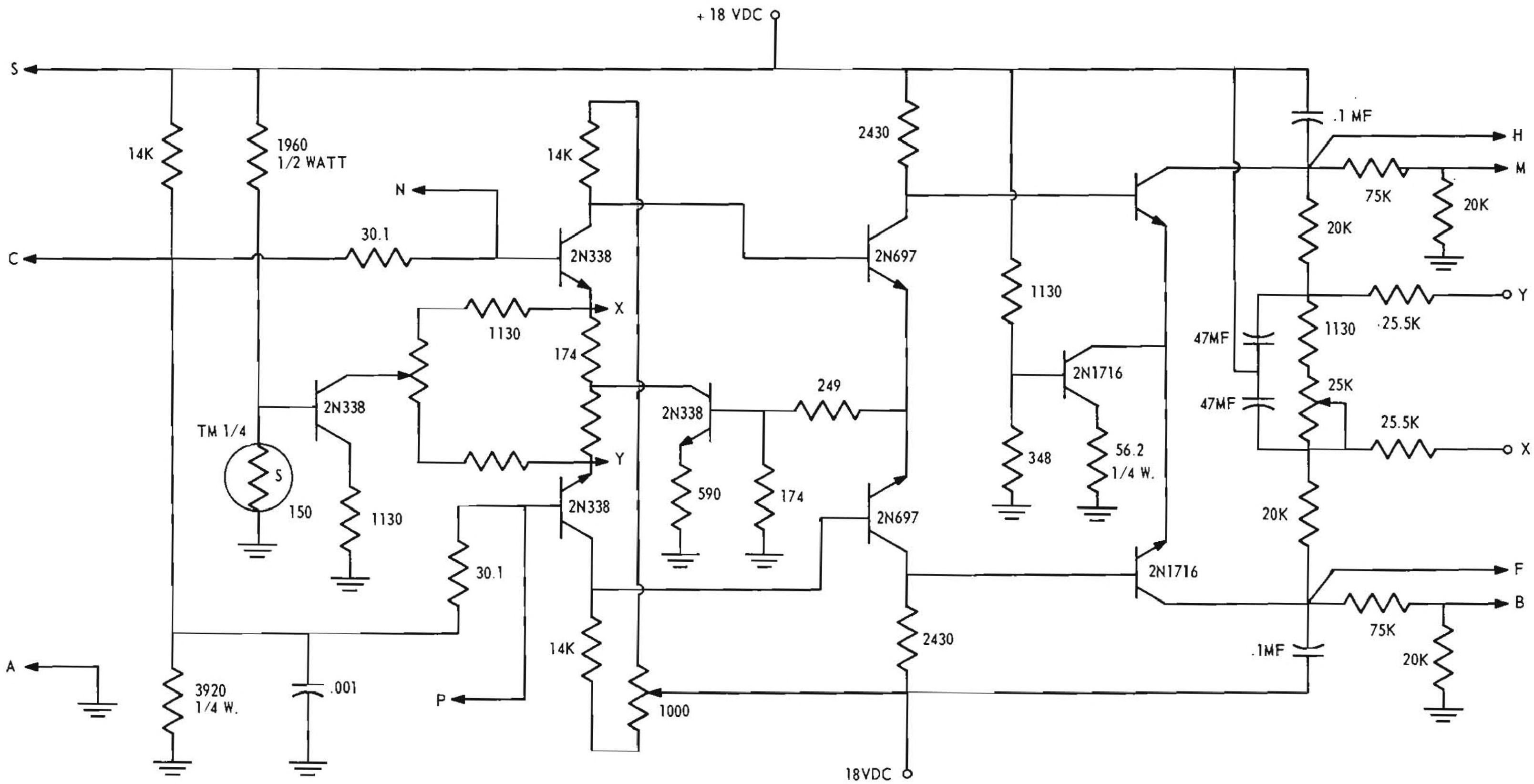

Figure 39. Pointing Control Amplifier Schematic.

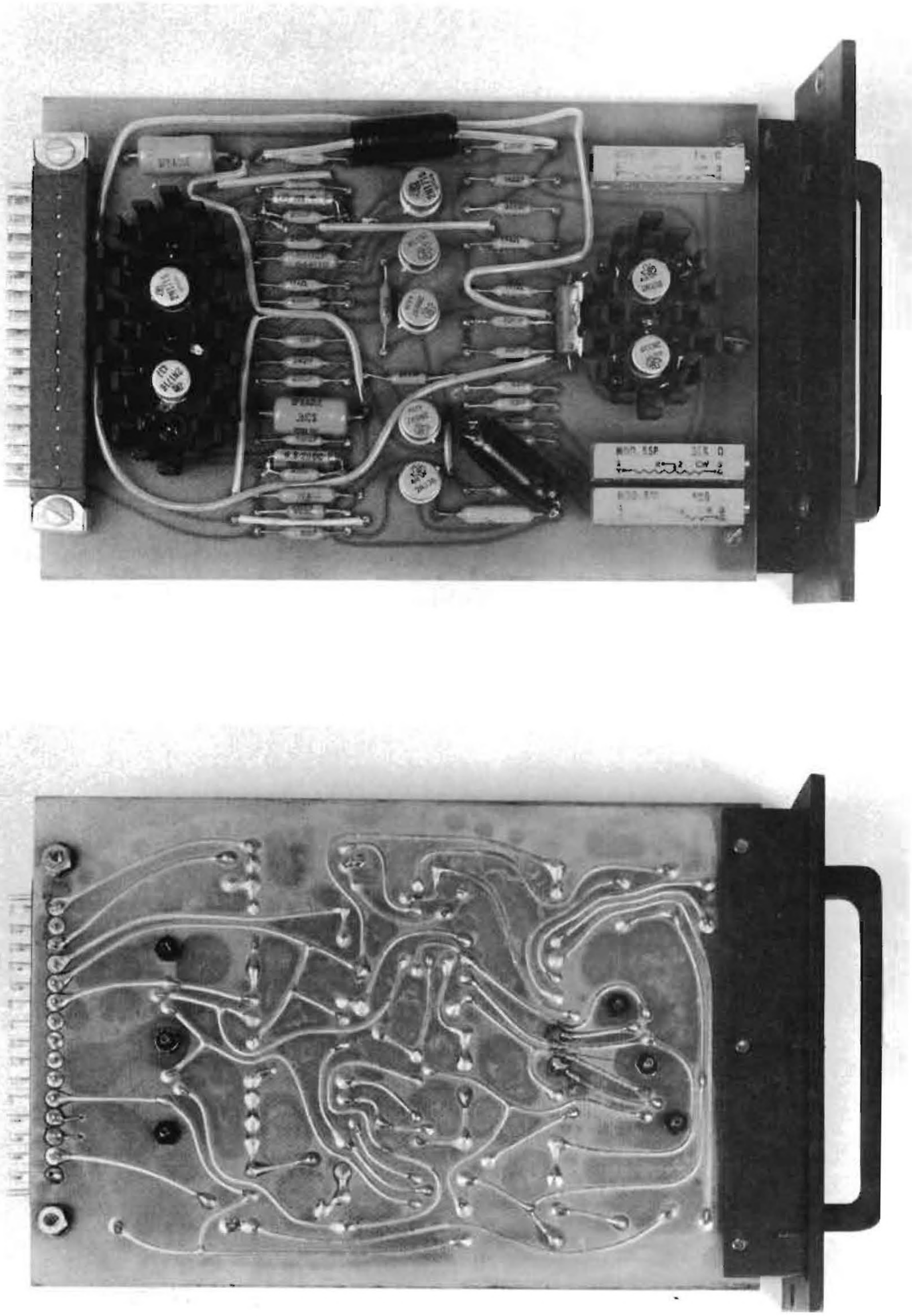

Figure 40. Pointing Control Amplifier Board.

bias which was considered an undesirable feature of the original sensor arrangement.

The input stage to the amplifier is a emitter coupled differential amplifier with a constant current source in the emitter circuit. A temperature sensitive resistor is included in the base circuit of the constant current source to compensate for the temperature dependent V_{BE} of the 2N338 transistors used in the differential input stage. The 500 potentiometer in the input emitter circuit is part of the temperature compensation network and is adjusted to cause the collector currents of the input transistors, with no signal input, to remain constant through the necessary temperature range. The fact that the collector currents remain constant with a change in temperature indicates that ΔV_{BE} of the individual transistors and the difference between ΔV_{BE_1} and ΔV_{BE_2} have been compensated for by the temperature sensitive resistor, the constant current source, and the potentiometer setting.

The second stage of the amplifier has a feedback path from the emitters through a single stage amplifier to the common emitter point on the input stage. The effect of this feedback path is to compensate for temperature variations of V_{BE} in the 2N697 transistors of the second stage and hence maintain the second stage collector currents independent of temperature. It is important that the second stage collector current and hence collector voltage remain constant with variations in temperature because the idling or bias current through the hysteresis clutches should be independent of temperature in order to maintain a fixed amount of coupling between the drive motors of the mounting frame. It is also necessary that the collector current of the output stage be independent of temperature for the same reasons. Therefore a constant current source was included in the emitter circuit of the output stage to insure that temperature variations did not effect the idling current through the clutches.

Degenerative feedback paths are provided from the output stage back to the input stage. A 30K potentiometer is used to adjust the amount of feedback and hence the overall gain of the amplifier. Capacitors were included in the feedback circuit to shape the frequency response of the system in order to eliminate mechanical oscillations of the system. These capacitors essentially decrease the negative feedback for an AC signal thereby providing an increase in overall gain for this AC signal. Thus, when the error sensors are being driven through the null position by the motor and clutches, more current is available to the clutches (and, therefore, more torque is produced) as the differential input voltage changes polarity. This effectively damps any mechanical oscillation caused by this electro-optical-mechanical feedback system.

The open loop gain was calculated to be 169,000, reduced to a range of 100 to 500 by the feedback network.

Temperature tests indicate that the bias point is adequately compensated for a temperature range of $-20^{\circ}C$ to $95^{\circ}C$, although there seemed to be a temperature dependency of the gain that became evident during the environmental testing at Holloman Air Force Base. This slight decrease did not constitute a problem since the circuitry is designed with an adequate safety margin for performance.

Telemetry

Purpose

In any experiment of this nature, some means must be provided to transfer the data from the flight package to the ground for eventual data reduction. Two means are generally available for this purpose: on-board tape recorders and telemetry. Each system has its definite advantages and disadvantages, and neither system is in itself the "perfect" system.

On-board recording systems require a tape recorder that usually has to be designed for the application, i.e., it must have the proper number of channels, must withstand the severe environment, and must have a sufficient recording time. Commerical units are available for this purpose, but it was decided that the advantages of telemetry outweighed the advantages for an on-board recording system. In order to be able to record for a sufficient period of time, say eight hours, the tape has to travel at a slow speed, but since some of the data could be DC, FM recording (where the input signal frequency modulates a carrier, which is then recorded on the tape) is required. Since the tape speed sets the frequency of the carrier which in turn sets the limit of the input frequency to the system, for a slow tape speed, the frequency response is accordingly low. Furthermore, since non-linear amplifiers are used in the phototube circuitry, in order to faithfully reproduce the output of the amplifiers, the frequency response for those channels in particular must be high. There are methods for avoiding this dilemma, but it was felt that the trouble did not justify the end. However, tape recording systems have the advantage that they require no support equipment on the ground, and the need for a telemetry antenna that projects beneath the gondola (which caused serious trouble on the first flight) is eliminated.

Telemetry systems, on the other hand, allow for real time evaluation of the data, and can be used to observe the performance of the flight package and to determine if it is operating properly. Telemetry, by its very nature, requires elaborate ground equipment and personnel and is somewhat more sensitive to the environment. However, the frequency response that is available can be as high as 2,100 cps, if required, although for this particular application, the highest frequency response that was used was 600 cps. Since all the recording of data is performed on the ground at the telemetry receiving site, the variables that influence the quality of the tape can be more rigidly controlled than an on-board recorder. The analog tape which is generated on the ground meets IRIG standards and can be easily handled by the data reduction (analog to digital, etc) equipment. Also since the data is recorded on the ground, time of day can be added to the tape so that the time recorded on the tape is actual time.

Standards for telemetry and other related fields are established by the Inter-Range Instrumentation Group (IRIG) to insure compatibility of air-borne transmitting equipment and ground receiving equipment and data-handling equipment at the test ranges.

Although for the most part, the telemetry system was considered to be a "black box" into which we put the data and eventually obtained it again on the ground, it is educational and helpful to understand some of the performance and operation of the system. The basic system (and the one that was in use during both flights) consists of an air-borne transmitter unit and a ground receiving station; additional receiving stations can be added if the distance covered by the experiment is such that one receiving station cannot receive the telemetered signal for 100% of the duration of the experiment.

The air-borne unit, which was to withstand the environment and where battery drain is a consideration, consists of four basic subassemblies: (1) the subcarrier oscillator, (2) the mixer amplifier, (3) the transmitter, and (4) the antenna. The subcarrier oscillators, which can range in number from 1 to 18 depending on the requirements of the experiment, are FM modulated oscillators operating in the range of 400 cps to 70 KC. These subcarrier oscillators accept an input voltage (or millivoltage, for some subcarrier oscillators) which modulates (changes the frequency) the oscillator in proportion to the amount of voltage present. The mixer amplifier accepts the FM modulated signal from the subcarrier oscillators and combines them to form one composite signal consisting of the outputs from all the subcarriers. The subcarriers are on different frequencies and the frequencies are spaced so that the subcarriers do not interfere with each other. The output from the mixing amplifier then frequency modulates the RF carrier in the transmitter which amplifies the RF carrier and delivers it to the antenna for radiation to the ground. This system is called a FM/FM system because the input voltage produces a FM subcarrier which in turn produces a FM carrier.

When the data is of a slowly varying nature that does not have to be sampled continuously, commutation is a method frequently used to place many pieces of intelligence on one subcarrier. In one method, pulse amplitude modulation (PAM), the commutation can be nothing more than a motor driven, continously rotating selector switch that switches a number of inputs in sequence to a single output. This output is then used as an input to a subcarrier oscillator as described in the preceding paragraph. In this type of commutation, all the pulses are of the same length, but their amplitude varies as the input voltage to the particular channel being sampled at the time. More sophisticated commutaters use solid state switching networks to replace the motor driven switch. Another type of commutation, pulse duration modulation (PDM), produces pulses of equal height or amplitude, but the length or duration of the pulse is proportional to the input to the particular channel being sampled at the time.

The ground receiving station has to obtain the various input signals from the composite signal that is transmitted by the flight package. The basic system consists of a receiver tuned to the transmitter frequency and a discriminator that retreives from the RF carrier the composite signal as it exists in the output of the mixer amplifier. This composite signal is then fed to another set of discriminators which separates the various subcarrier frequencies and demodulates the subcarrier to obtain a voltage which is proportional to the input voltage to the subcarrier oscillators in the air-borne package. In this set of discriminators, various filters can usually be selected that give the proper wave shaping and frequency response as is necessary. If one of the subcarriers contains commutated data, for real time presentation, the output from the appropriate discriminator are fed to a decommutator, which electronically separates the various commutator inputs sequencially and produces a voltage for each channel of input which is proportional to the input voltage to the commutator. This is true for both PAM and PDM commutation, the only difference being in the electronics of the decommutator.

After the voltage has been obtained that is proportional to the input to the subcarriers, these voltages can be recorded or displayed in any manner which is feasible and available. Oscillographs, strip charts, and tape recorders are the most common methods, although others do exist. However, for data reduction, the raw telemetered signal (the composite signal obtained after the first demodulation) is usually recorded on magnetic tape along with other pertinent information, i.e. signal strength, range time codes, etc.), and the second demodulation is performed at the data reduction facilities.

The specific air-borne package that was flown also had a DC-DC converter that regulated the voltage to the subcarrier oscillators and mixer amplifier and also provided high voltage (+250) for the plate circuits of the RF transmitter. The antenna that was used was turnstile antenna, a drawing of which is shown in figure 41. The power output from the transmitter was approximately 5 watts and the power requirements were 7.5 volts DC at 6 amperes.

The telemetry package was built by Northeastern University*, who also supplied support facilities and personnel for the flight. The transmitter was built by Telemet Company, Amityville, L. I., N. Y. and is their model 1483-A1 serial #1462. The subcarrier oscillators were manufactured by Vector Manufacturing Company, Inc., Southhampton, Pa. and were their model 30 and 30A. A table of frequencies and serial numbers follows;

Frequency	Serial #	Model
0.96 KC	A787-5	TR30A
1.3	1520-5	TR30
10.5	A456-5	TR30A
14.5	A475-5	TR30A
22.0	B311-5	TR30A
30.0	A205-5	TR30A
40.0	A595-5	TR30A

The mixer amplifier, also by Vector Manufacturing Company, was model TR36,

*Northeastern University, Electronics Research Project, Greenleaf Building, Boston, Massachusetts, 617-CO2-1100 (Extension 255)

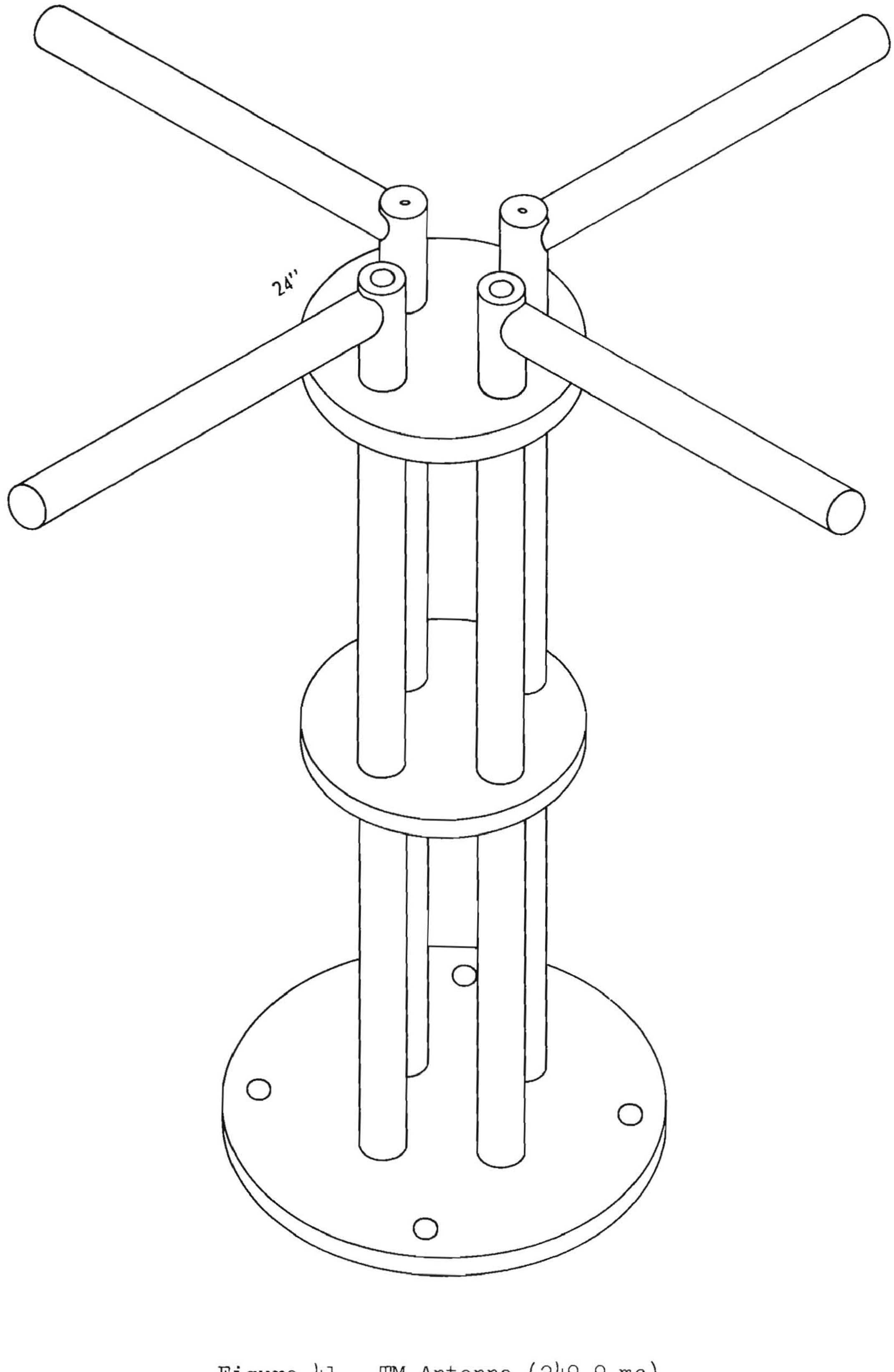

Figure 41. TM Antenna (249.9 mc).

serial #468. The DC-DC converter was made by Electronic Development Corporation, 423 W. Broadway, Boston, Mass. (617-268-9696) and is their model TCD-7A, serial #1462. The system did not seem to function well for the 1 July flight, and it was first believed that the subcarrier oscillators were too temperature sensistive. Considerable data was lost during the ascent portion of the flight when the system was subjected to cold temperatures. The ground receiving stations are operated at Holloman Air Force Base by Land Air, Inc.** The personnel are quite willing to help the contractor and will try to accomodate whenever it is possible.

Optics

Spectrometer

The Ebert spectrometer was chosen for its ruggedness, simplicity of optical design, and overall sensitivity. This same type of spectrometer has been popularized by W. G. Fastie of John Hopkins University, and is frequently referred to as a Ebert-Fastie spectrometer. The mechanical construction of the spectrometer is such that it can easily withstand the forces encountered during the balloon flight, since Fastie uses the same type unit in Aerobee rockets for high altitude probes. There are only two active optical elements besides the slits in the spectrometer, the grating and the spherical mirror, so optical alignment is not complicated. The f-number for the system is given by the ratio of the focal length to the width of the grating, and for an Ebert mount, the f-number can be made relatively small as compared to other spectrometers.

**Land Air, Inc., P. O. Box 394, Holloman Air Force Base, New Mexico, 505-473-6181, Harry Gattin, Fred Flores.

The grating is a Bausch and Lomb Number 33-53-15-04, serial number 619A55B1. This is a 102 x 102 mm plane grating, 2160 grooves/mm, blazed at 3000 Å. According to the manufacturer it has a minimum efficiency of 51% at 2752 Å, 55% at 3340 Å, and 60% at 3650 Å. The resolving power is greater than 93% of the theoretical value, and the intensity of the first ghost is 0.14% of the parent at 5461 Å in the first order.

The circular slits are 60 mm long and are on a $2\frac{1}{2}$ inch radius of curvature. The entrance slit was set to approximately 0.2 mm while the exit slit was set to 2.0 mm. The entrance slit was set so that the sensitivity of the instrument was such to produce an "on-scale" reading from the detector, while the exit slit was adjusted so that the desired resolution (20 Å) was obtained.

The mirror is a 10", 1 meter radius spherical front-surface mirror. The size of the mirror and grating permits a 12° acceptance angle for the incident light, and the f-number for the system is 5.

The wave length relation for the Ebert geometry is

$$n\lambda = 2\,d\cos\varphi\sin\theta$$

where n is the spectral order, λ is the wave length that appears at the exit slit, φ is the angle between the axis of symmetry and the light incident upon the grating, and θ the angle between the grating normal and the axis of the instrument (see figure 42). Nominally φ is $\sin^{-1} W/R$, where W is the grating width and R the radius of curvature of the mirror, but in practice it can differ from this value. Other dimensions than W and R could nominally define φ just as well. In any event, φ is a fixed angle in any given Ebert spectrometer. Also, the diffracted radiation of inter-

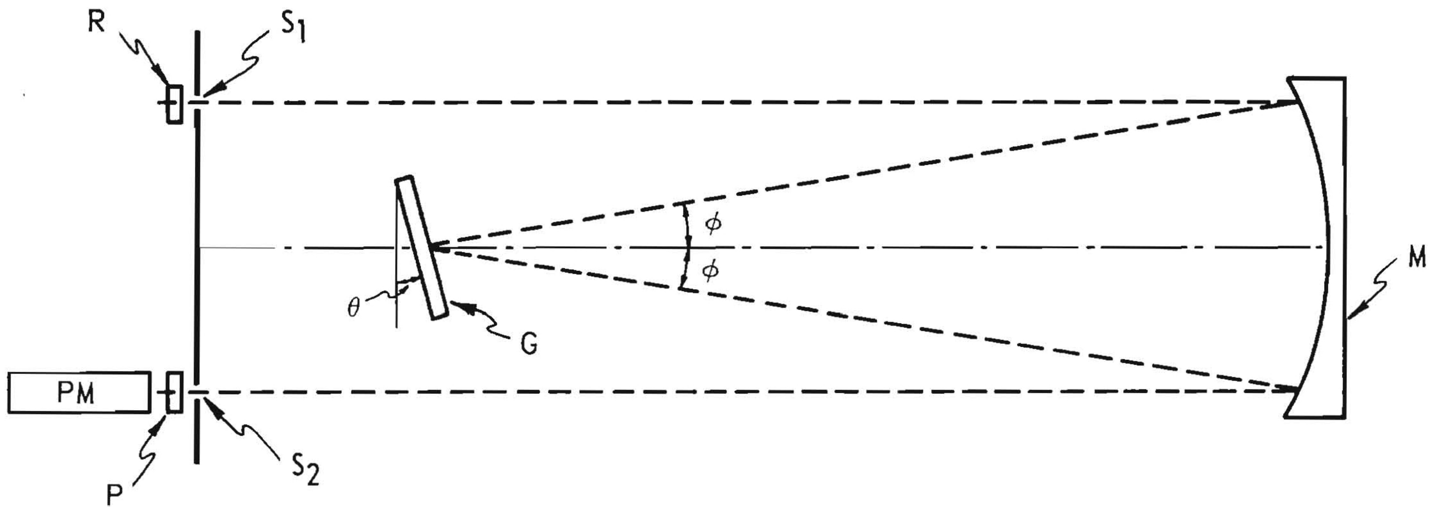

Figure 42. Optical Arrangement of the Ebert-Fastie Spectrophoto-polarimeter.

est leaves the grating in a beam that makes the same angle with the instrument axis.

For 2000 Å, the wave length relation for θ gives

$$1 \cdot 2000 \times 10^{-7} = \frac{2}{2160} \cos 5.85^{\circ} \sin \theta$$

$$\theta = 12.5^{\circ} \quad .$$

For 4000 Å, the wave length relation gives for θ

$$1 \cdot 4000 \times 10^{-7} = \frac{2}{2160} \cos 5.85^{\circ} \sin \theta$$

$$\theta = 24.8^{\circ} \quad .$$

In order to determine what interference would be present from overlapping orders, let us examine what the second order produces at the exit slit when the grating has 2000 and 4000 Å on the exit slit from the first order. From the wave length relation for 2000 Å

$$2 \cdot \lambda = \frac{2}{2160} \cos 5.85^{\circ} \sin 12.5^{\circ}$$

$$\lambda = 1000 \text{ Å} \quad .$$

For 4000 Å in the first order, the second order gives

$$2 \cdot \lambda = \frac{2}{2160} \cos 5.85^{\circ} \sin 24.8^{\circ}$$

$$\lambda = 2000 \text{ Å} \quad .$$

Hence, the second order should not present any problem since it is in the vacuum ultraviolet region of the spectrum. At 4000 Å, the 2000 Å from the second order might be intense enough to excite the 2000 to 3200 Å "solar blind" PM tube, but since this is essentially dead at 4000 Å, it could easily be distinguished as the second order appearing at the exit slit.

The problem of a slit limited resolution spectrograph, which is what is employed, brought out just how a spectrograph behaves when illuminated by light from a distant, extended source, each element of which radiates light that is incoherent with all other elements. This problem is answered in another publication.[6]

To align the spherical mirror, the optical axis of the instrument was defined by a cross hair at the center of the slit circle and a cross hair in the body of the instrument. The mirror was coarse adjusted by using the image of the cross hairs and fine adjusted with a Foucault knife edge test[7] to position its center of curvature on the optical axis of the instrument. The actual adjustment of the mirror is made by three Allen head nylon-tipped screws on the back of the mirror which act against three similarly positioned nylon-tipped studs which are mounted in the body of the spectrometer. Adjustment of the Allen head screws compresses the nylon so that the mirror will move slightly. Initially, when large adjustment of the mirror position was required, the studs had to be removed and filed so that the mirror could be positioned properly.

The plane of the grating was adjusted by using the central image of the entrance slit so that the image of the entrance slit matches the shape of the exit slit by a push-pull screw arrangement on the back of the grating holder. The rotation of the grating (the rulings are not necessarily parallel to the sides of the blank) was adjusted by using various spectral lines (in this case, the visible mercury lines were used) so that the spectral line filled the exit slit, i.e., the image of the entrance slit matched the exit slit. The rotation adjustment is made by two counteracting screws located on opposite sides of the grating holder.

The focus of the instrument, and more particularly the mirror, is checked by observing the image of the entrance slit at the exit slit using a microscope (low-powered) focused on the exit slit. When the instrument is in focus, as the central image (zero order) is passed over the exit slit, the image of the entrance slit at the exit slit will also be in focus. The focusing adjustment is the same three Allen screws that adjusts the optical axis of the instrument, but in this adjustment, all the screws are moved equally in order to move the mirror as a whole forward or backward, depending on the need. The image of the entrance slit was checked before and after the last flight and found to be sharp but about one millimeter inside the instrument. It was determined that this would not noticeably affect the performance of the instrument and no attempt was made to obtain a better focus.

Since polarization is a problem with an Ebert mount, some method of analyzing the polarization of the incident light was decided upon over elimination of the polarization sensitivity of the spectrometer. A Sekera-type polarimeter was constructed and attached to the instrument, and the mathematics envolving from the use of retardation plates and linear polarizers such as in this polarimeter need some explanation. This polarimeter requires a linear polarizer as part of the optical train, but since no polarizer could be found that would transmit sufficiently below 2300 Å, the instrument itself, which is an imperfect polarizer, was used for the linear polarizer for the 2000 to 3200 Å tube.

The mathematics involved in polarized light has been described in great detail elsewhere[8], but the rudiments which are applicable to this particular case will be presented here. Basically, the concept is that any form of polarized light or unpolarized light can be represented by a 4 element column vector, while any optical device,--polarizer, retardation plate, filter, etc.--can be represented by a 4 x 4 matrix. In order to determine the nature of light that passes through an optical device, it is only necessary to operate on the column vector which represents the incident light by the matrix which represents the optical device. The resulting four element column vector (Stokes vector) describes the transmitted light.

Stokes Parameters and Mueller Calculus

Completely or partially polarized light can be specified by a set of four quantities known as the Stokes parameters, all of which have the dimensions of intensity. These four parameters are usually represented by a column vector as:

$$\begin{bmatrix} I \\ Q \\ U \\ V \end{bmatrix} \tag{1}$$

The first parameter, I, is to be interpreted as the total intensity of the light, and the remaining Stokes parameters lead to the following inequality:

$$I^2 \geq Q^2 + U^2 + V^2 \quad . \tag{2}$$

The intensity is equal to the square root of the sum of the other three only if the beam is completely polarized. It is convenient to define the degree of polarization, P, as:

$$P = \frac{(Q^2 + U^2 + V^2)^{\frac{1}{2}}}{I} \tag{3}$$

If Φ is the angle which the major axis of the elliptically polarized light (as a special case, linearly polarized light) makes with the reference axis (figure 43), then

$$\begin{aligned} I &= I \\ Q &= PI \cos 2\Phi \\ U &= PI \sin 2\Phi \\ V &= V \end{aligned} \tag{4}$$

and the quantities I, P, V, and Φ will be designated as the modified Stokes parameters.

In Mueller calculus, an optical device is represented by a 4 x 4 matrix which operates on the Stokes vector of the incident light to give the Stokes vector of the transmitted (or reflected) light. For a nonperfect linear polarizer, let r_p represent the ratio of the minor axis transmission to the major transmission (ideally, $r_p = 0$). The Mueller matrix for such an imperfect plane polarizer is:

$$[P_o] = C_p \begin{bmatrix} 1 + r_p^2 & 1 - r_p^2 & 0 & 0 \\ 1 - r_p^2 & 1 + r_p^2 & 0 & 0 \\ 0 & 0 & 2r_p & 0 \\ 0 & 0 & 0 & 2r_p \end{bmatrix} \tag{5}$$

where C_p is a normalization constant.

For an imperfect retardation plate of retardance δ with its fast axis

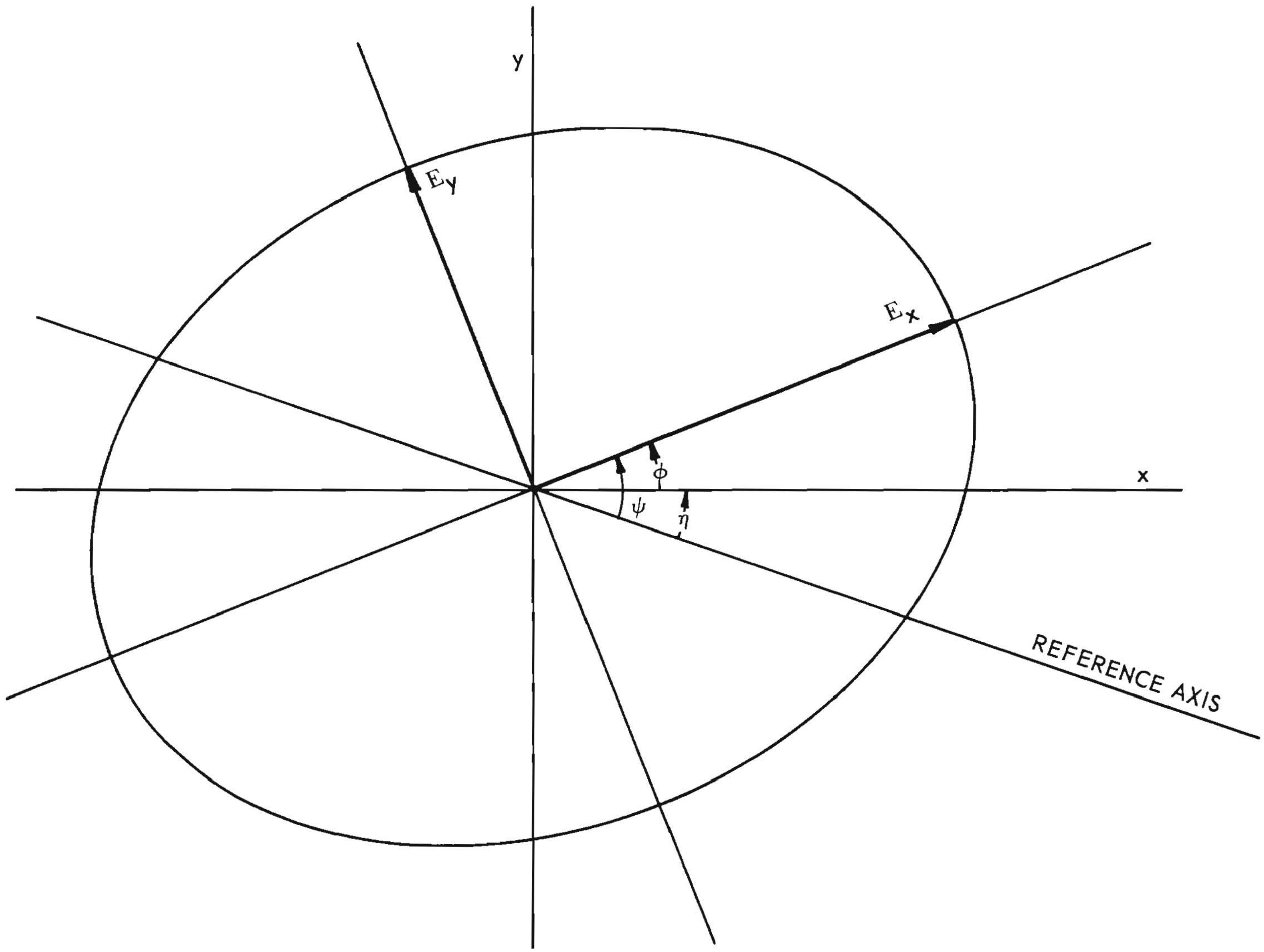

Figure 43. Nomenclature for Polarized Light Used in the Text.

displaced from a reference axis by an angle β, the Mueller matrix can be shown in equation 6, where r_r is the ratio of the slow axis transmission to the fast axis transmission (ideally, $r_r = 1$), and C_r is a normalization constant.

Matrix Representation of the Spectro-Photopolarimeter

By placing an imperfect retardation plate of retardance δ in front of a fixed imperfect linear polarizer (in this case, the entire spectrometer system and polarizer), the intensity and the other Stokes parameters can be found from:

$$[A] = [P_o]\,[R_\beta]\,[I] \tag{7}$$

where $[A]$ is the Stokes vector of the light leaving the linear polarizer, $[I]$ is the Stokes vector of the incident light, and $[P_o]$ and $[R_\beta]$ are defined by equations 5 and 6 respectively. The signal out of the photomultiplier tube is proportional to the intensity of light striking the photocathode, which can be separated into components of β as follows:

the D.C. component:

$$a_1 = CI\left(1 + r_p^2\right)\left(1 + r_r^2\right) + \tfrac{1}{2}\left(1 - r_p^2\right)\left(1 + r_r^2 + 2r_r \cos\delta\right)P\cos 2\phi \tag{8a}$$

the sin 2β component:

$$a_2 = CI\left(1 + r_p^2\right)\left(1 - r_r^2\right)P\sin 2\phi + 2Vr_r\left(1 - r_p^2\right)\sin\delta \tag{8b}$$

the cos 2β component:

$$a_3 = CI\left(1 - r_p^2\right)\left(1 - r_r^2\right) + \left(1 + r_p^2\right)\left(1 - r_r^2\right)P\cos 2\phi \tag{8c}$$

$$
[R_\beta] = C_r \begin{bmatrix}
1 + r_r^{\,2} & \left(1 - r_r^{\,2}\right) \cos 2\beta & \left(1 - r_r^{\,2}\right) \sin 2\beta & 0 \\
\left(1 - r_r^{\,2}\right) \cos 2\beta & \begin{array}{c} \frac{1}{2}\left(1 + r_r^{\,2} + 2r_r \cos \delta\right) + \\ \frac{1}{2}\left(1 + r_r^{\,2} - 2r_r \cos \delta\right) \cos 4\beta \end{array} & \frac{1}{2}\left(1 + r_r^{\,2} - 2r_r \cos \delta\right) \sin 4\beta & 2r_r \sin \delta \sin 2\beta \\
\left(1 - r_r^{\,2}\right) \sin 2\beta & \frac{1}{2}\left(1 + r_r^{\,2} - 2r_r \cos \delta\right) \sin 4\beta & \begin{array}{c} \frac{1}{2}\left(1 + r_r^{\,2} + 2r_r \cos \delta\right) - \\ \frac{1}{2}\left(1 + r_r^{\,2} - 2r_r \cos \delta\right) \cos 4\beta \end{array} & -2r_r \sin \delta \cos 2\beta \\
0 & -2r_r \sin \delta \sin 2\beta & 2r_r \sin \delta \cos 2\beta & 2r_r \cos \delta
\end{bmatrix} \tag{6}
$$

the sin 4β component:

$$a_4 = \tfrac{1}{2}\, CI \left(1 - r_p^{\,2}\right)\left(1 + r_r^{\,2} - 2r_r \cos \delta\right) P \sin 2\Phi \tag{8d}$$

the cos 4β component:

$$a_5 = \tfrac{1}{2}\, CI \left(1 - r_p^{\,2}\right)\left(1 + r_r^{\,2} - 2r_r \cos \delta\right) P \cos 2\Phi \tag{8e}$$

After the components a_1, a_2, a_3, a_4, and a_5 are determined by some method of harmonic analysis, then the unknown quantities, the modified Stokes parameters of the incident light, I, P, V, and Φ, are given by:

$$I = \frac{1}{C\left(1 + r_p^{\,2}\right)\left(1 + r_r^{\,2}\right)} \left[a_1 - \frac{\left(1 + r_r^{\,2} + 2r_r \cos \delta\right)}{\left(1 + r_r^{\,2} - 2r_r \cos \delta\right)}\, a_5 \right] \tag{9}$$

$$P = \frac{2\left(a_4^{\,2} + a_5^{\,2}\right)^{\frac{1}{2}}}{CI\left(1 - r_p^{\,2}\right)\left(1 + r_r^{\,2} - 2r_r \cos \delta\right)} \tag{10}$$

$$V = \frac{a_2 - CI\left(1 + r_p^{\,2}\right)\left(1 - r_r^{\,2}\right) P \sin 2\Phi}{2CI\, r_r \left(1 - r_p^{\,2}\right) \sin \delta} \tag{11}$$

$$\Phi = \tfrac{1}{2} \tan^{-1}\left(\frac{a_4}{a_5}\right) \quad . \tag{12}$$

Equations 9 through 12 will therefore determine the modified Stokes parameters of the incident light from the Fourier components of the exit intensity as a function of β. To obtain these components analog techniques could be used, but in this particular application, a digital method of curve fitting was employed to obtain a_1, a_2, a_3, a_4, and a_5.

Effect of Imperfect Optical Elements

Since it was known beforehand that the optical components used were not perfect, it was necessary to determine the effect of such imperfect elements in the optical train. The main component to consider is the linear polarizer, since it is not nearly as perfect as the Glan-Thompson prism used by Sekera. Also, since the spectrometer covered a wide wave length region, a dependence on wave length may be considered an imperfection and must be considered. The relationships expressed in equations 9 through 12 form the basis for determining the effect of imperfect optical elements on the determination of the Stokes parameters.

It can be seen that if r_p is known with a fair degree of accuracy and is not unity, then all the polarization parameters can be uniquely determined. If r_p were unity, i.e. no polarizer, then although P, V, and Φ could not be determined, I could be measured, and the requirement for a polarimeter would vanish. While P is proportional to $1/(1 - r_p^2)$, V is essentially proportional to $1/(1 - r_p^2)^2$, so any error in the determination of r_p will have some effect on P, but it would have a greater effect upon the measurement of V.

Other imperfect optical elements will have an effect on the determination of the Stokes vector of the incident light. Investigating the effect of the retardance of the phase plate on the Stokes parameters, we find that if $\delta = 0$ or 180^0, then although V could not be determined, I, P, and Φ could. As expected, $\delta = 90^0$ leads to no difficulty in any determination. The other extreme on the phase plate would be if $r_r \doteq 0$, which would correspond to the phase plate being a perfect linear polarizer. If this were the case, then again V could not be determined, but I, P, and Φ could be.

In general, the requirements placed on the optical elements in the train would be that in the wave length region of interest $r_p < 1$, $r_r > 0$, $0^o < \delta < 180^o$, and obviously, $C > 0$. If these conditions are satisfied, then the four modified Stokes parameters, and consequently, the Stokes parameters themselves, of the incident light can be uniquely determined. However, even with these conditions fulfilled and all optical components properly calibrated, thermionic emission in the photomultiplier tube and other sources of noise in the system may seriously affect the measurements if, for example, r_p were close to unity. Therefore, the practical limit on the size of r_p, r_r, δ, and C which can be tolerated is set by experimental conditions.

It is anticipated that C will show a strong wave length dependence since it includes, among other things, the spectral response of the photomultiplier tube, δ will exhibit a medium wave length dependence, and r_r and r_p will have some slight wave length dependence. The polarimeter-spectrometer would have to be calibrated at as many wave lengths as possible in order to observe these wave length dependencies and also to judge a reasonable confidence level which can be placed on the results.

Optical Calibration

Objective

Since qantitative data was required to measure the skylight intensity, the optical system of the instrument had to be calibrated in terms of watts per cm^2 per volt out. One method of such a calibration is to measure the characteristics of each component in the optical train and then figure the combined characteristic from the individual ones. However, for expediency and simplicity, a method was devised that permitted the optical calibration of the spectro-photopolarimeter in a maximum of two steps. It is possible with this method to actually calibrate the system in one step, if one knows the quantitative amount of light passing through an auxiliary polarizer. There is one serious disadvantage to this method, and that is the quantity of data that is required for calibration. Hand reduction of this data is practically impossible from the time standpoint, and therefore, the computational procedures have to be programmed for the computer. In this line, however, another problem arises and that is the generation of the data in a form that is usable by the computer, but this problem is essentially solved as well as the means of reducing the large volume of calibration data. An analog-to-digital converter (ADC) at Telecomputing Services, Inc. uses the analog tape which is generated by the calibration procedure and produces a digital tape in IBM 7094 format which can be used on Georgia Tech's computer. Thus the entire problem of data handling is essentially alleviated by computer and computing machinery.

The basic problem of calibration can be broken into three categories: (1) the calibration of the quarter wave plate as to retardance, transmission, and linear polarization, (2) the calibration of the spectrometer for transmission and linear polarization, and (3) the calibration of the photomultiplier tubes for spectral response. The third problem is best solved by means of an NBS Standard of Spectral Irradiance[9] for which NBS has calibrated the light output versus wave length. It is assumed, however, that transmission losses in the optical train can be accounted for by modifying the spectral response of the photomultiplier tubes. Thus, the spectral response which the calibration procedure produces is quite likely to differ from the spectral response furnished by the manufacturer.

For all the different calibrations except the quantitative value of light input versus voltage output, the procedure is fairly simple. A suitable light source (a GE quartz-iodine lamp was used) is placed behind a linear polarizer that can be rotated in fixed increments. The light from this polarizer is then allowed to fall on the entrance slit of the spectrophotopolarimeter. The output is then recorded by some means, either through telemetry onto magnetic tape recorders or by oscillographs, from which the data is obtained by ADC or hand reduction, respectively. The angle of polarized light is stepped in its fixed increments until at least 180° have been passed. For a given wave length, a output is first broken down into components of the rotating quarter wave plate frequency, and then these components are reduced into components of the angle of incident polarization. The system has the distinctly advantageous property that no optical component (quarter wave plate, linear polarizers, etc) have to be perfect because the system allows for imperfections in these devices and actually computes the amount of imperfection.

The calibration for the quantitative value requires just the NBS standard of spectral irradiance which is placed before the entrance slit. The output of the photomultiplier tube is analyzed into components of the rotating quarter wave plate frequency, and the value of the transmission coefficient for the entire system is calculated.

Specific Procedure

An accessory was constructed that was capable of rotating (by a Ledex digimotor) in fixed increments of 11.25 degrees a linear polarizer that was made from a sheet of Polaroid HNB. For the first part of the calibration procedure, this accesory was placed between the light source, a GE quartz-iodine lamp, and the entrance slit of the spectrophotopolarimeter. The polarizer was then rotated by manually pushing a switch at a time which corresponded to the return sweep of the grating. Thus, every twenty seconds, the polarizer was rotated, which means that throughout the calibration run, for every sweep of the grating through the wave length region there was a different angle of polarization of incident light.

For the second part of the calibration procedure, the NBS standard of spectral irradiance was placed a known distance (61.2 cm) from the entrance aperature of the spectrophotopolarimeter. Although this is not the distance at which the lamp was calibrated, it is reported that the inverse square law is valid at distances over 43 cms. Several wave length scans were made with the standard lamp as the light source to serve for calibration purposes.

The calibration procedure is definitely computer oriented. A large volume of data is accumulated, and some of the calculations although they could be calculated using a desk calculator, are best left for the digital computer. For the utilization of the digital computer, a method of multiple linear regression was used which minimizes a function, G, of the form:

$$G = \sum_{i=1}^{N} \left[y_1 - a_1 - a_2 x_{1i} - a_3 x_{2i} - a_4 x_{3i} - a_5 x_{4i} \right]^2 \tag{13}$$

where, in this case, y_i is the photomultiplier tube output corrected for dark current, $x_{1i} = \sin 2\beta_i$, $x_{2i} = \cos 2\beta_i$, $x_{3i} = \sin 4\beta_i$, and $x_{4i} = \cos 4\beta_i$, where β_i corresponds to the β in 3.2 and the $i^{\underline{th}}$ value of y.

Equation 8 can be placed in the following form:

$$I_A = a_1 + a_2 \sin 2\beta + a_3 \cos 2\beta + a_4 \sin 4\beta + a_5 \cos 4\beta \tag{14}$$

which gives the PM tube signal in terms of components of β. However, if β is not known, but a relative angle, θ, is known, then

$$\beta = \theta + \zeta \tag{15}$$

and I_A can be expanded in terms of θ in a form

$$I_A = b_1 + b_2 \sin 2\theta + b_3 \cos 2\theta + b_4 \sin 4\theta + b_5 \cos 4\theta \tag{16}$$

and a harmonic analysis of I_A will yield b_1, b_2, b_3, b_4, and b_5.

As before, if the angle φ is not known, but a relative angle, ψ, is known, then

$$\varphi = \psi + \eta \tag{17}$$

and if we define

$$\xi_1 = \eta - \zeta \tag{18a}$$

$$\xi_2 = \eta - 2\zeta \tag{18b}$$

then by equations 8 and 15 the coefficients in equation 16 can be placed in the form:

$$b_1 = c_{11} + c_{12} \sin 2\psi + c_{13} \cos 2\psi \tag{19a}$$

$$b_2 = c_{21} + c_{22} \sin 2\psi + c_{23} \cos 2\psi \tag{19b}$$

$$b_3 = c_{31} + c_{32} \sin 2\psi + c_{33} \cos 2\psi \tag{19c}$$

$$b_4 = c_{42} \sin 2\psi + c_{43} \cos 2\psi \tag{19d}$$

$$b_5 = c_{52} \sin 2\psi + c_{53} \cos 2\psi \tag{19e}$$

If measurements are taken for several values of ψ, then each component of 16 can be expanded in components of ψ, and all the c's can be determined. It then follows that

$$\eta = \tfrac{1}{2} \tan^{-1}\left(\frac{-c_{12}}{c_{13}}\right) \tag{20}$$

$$\xi_1 = \tfrac{1}{2} \tan^{-1}\left(\frac{c_{23}}{c_{22}}\right) = \tfrac{1}{2} \tan^{-1}\left(-\frac{c_{32}}{c_{33}}\right) \tag{21}$$

$$\xi_2 = \tfrac{1}{2} \tan^{-1}\left(\frac{c_{43}}{c_{42}}\right) = \tfrac{1}{2} \tan^{-1}\left(-\frac{c_{52}}{c_{53}}\right) \tag{22}$$

$$\xi = \eta - \xi_1 = \tfrac{1}{2} (\eta - \xi_2) \tag{23}$$

Although it is possible to obtain the calibration parameters from the explicit form for the c's, it is somewhat more straightforward if the defining relationships of 15 and 17 are used to expand I_A first in components of β as in 8 and then the coefficients in terms of φ as

$$a_1 = d_1 + d_2 \cos 2\varphi \tag{24a}$$

$$a_2 = d_3 + d_4 \sin 2\varphi \tag{24b}$$

$$a_3 = d_5 + d_4 \cos 2\varphi \tag{24c}$$

$$a_4 = d_6 \sin 4\varphi \tag{24d}$$

$$a_5 = d_6 \cos 4\varphi \tag{24e}$$

From these relationships, the calibration parameters can be determined as follows:

$$r_r = \sqrt{\frac{1 - k}{1 + k}} \qquad (25)$$

$$\cos \delta = \frac{d_2 - d_6}{d_2 + d_6}\left(\frac{1 + r_r^2}{2r_r}\right) \qquad (26)$$

$$r_p = \sqrt{\frac{kd_1 - d_5}{kd_1 + d_5}} \qquad (27)$$

$$CI = \frac{d_1(1 + k)}{2(1 + r_p^2)} \qquad (28)$$

where

$$k = \sqrt{\frac{d_4 d_5}{d_1(d_2 + d_6)}} \qquad (29)$$

If the total intensity of light falling on the entrance aperture after passing through the polarizer is known, then C can be determined from 28. However, if a separate determination is needed to determine C, then, after performing the required harmonic analysis on the PM tube signal, C can be found from

$$C = \frac{1}{I\left(1 + r_p^2\right)\left(1 + r_r^2\right)}\left[a_1 - \frac{\left(1 + r_r^2 + 2r_r \cos \delta\right)}{\left(1 + r_r^2 - 2r_r \cos \delta\right)} a_5\right] \qquad (30)$$

If the source is completely unpolarized, then P = 0, and consequently, $a_5 = 0$.

Calibration is complete after the determination of C, whether it comes from equation 28 or 30. No "perfect" optical components, except perhaps for an unpolarized light source, are used, and the calibration could be performed in just one operation. Individual components are not calibrated as such, rather the entire spectrometerpolarimeter is calibrated as a basic unit.

The basic computer program for the calibration procedure is shown in Appendix C while the flow diagram for this program is shown in figure 44. The input tape for this program has all four FM channels digitized and the wave length calculated for the forward sweep of the grating. During the return sweep of the grating no wave length computation is attempted. Input parameters to the program are in the following format, right justified:

	Columns	Description
Card 1	1-4	Number of angles of incident polarization
	5-8	Number of sample points per angle of incident polarization
	9-12	The number of wave lengths at which calibration is desired
Card 2	1-6	Starting time for calibration procedure
	7-12	Digitized value to indicate a change of angle of incident polarization
	13-18	Wave length below which only the 541F tube is calibrated
	19-24	Wave length above which only the 541A tube is calibrated
Card 3	1-10	Interval to dump program
	11-20	Approximate frequency of AC generator
	21-30	Incremental change of angle of incident polarization
	31-40	η for the 541F tube (if known)
	41-50	η for the 541A tube (if known)
	51-60	ζ for the 541F tube (if known)
	61-70	ζ for the 541A tube (if known)
Card 4	1-2	Compute option for first AC generator approximation
	3-4	Compute option for second AC generator approximation
	5-6	Compute option for first pass of PM current data
	7-8	Compute option for first pass of component data
	9-10	Compute option for second pass of PM current data
	11-12	Compute option for second pass of component data

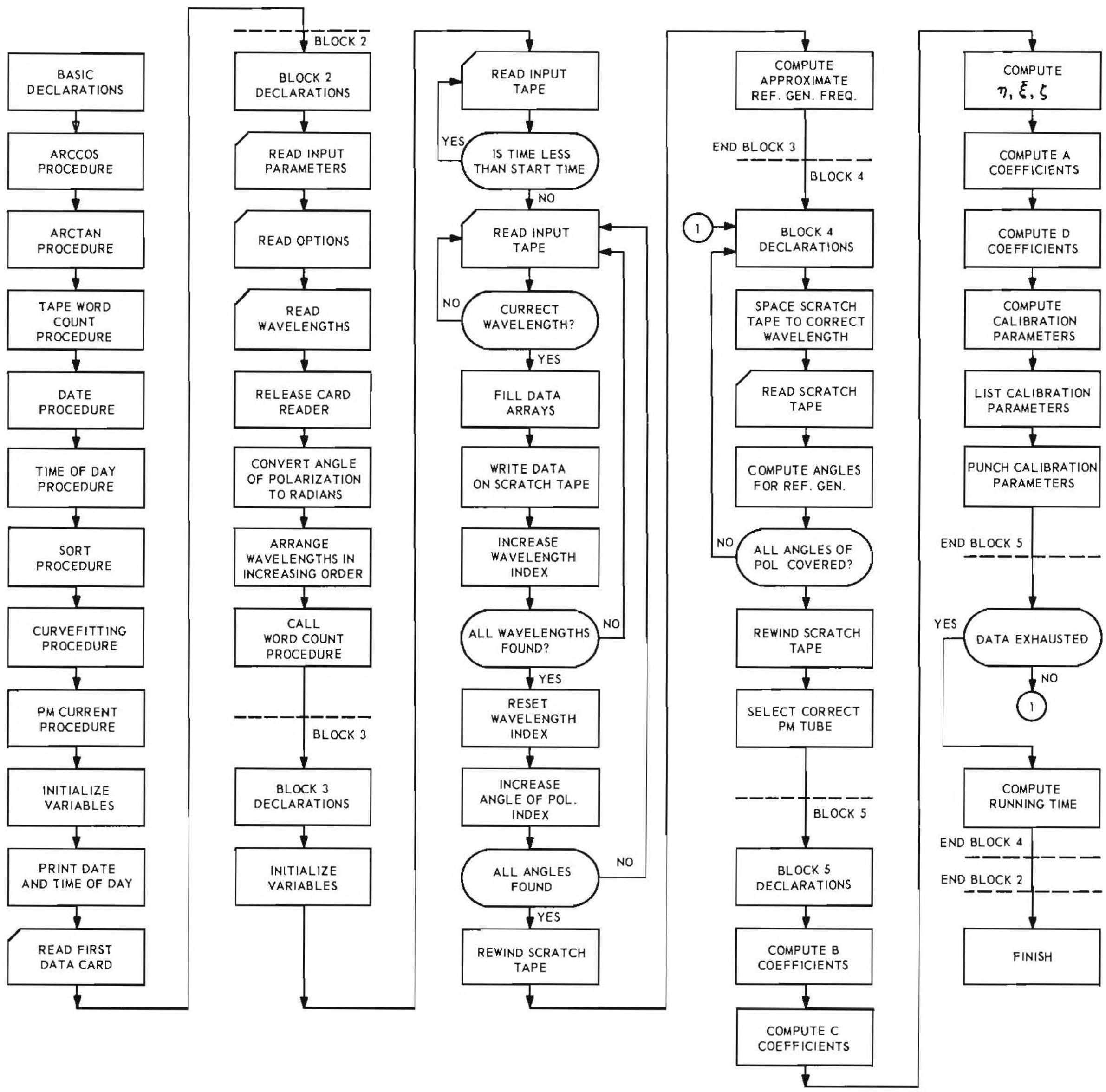

Figure 44. Calibration Program Flow Chart.

	21-25	TRUE if the input data is to be listed, FALSE otherwise.
	26-30	TRUE if the times at which the calibration wave lengths occurred are to be listed, FALSE otherwise
	31-35	TRUE if AC generator frequency iterations are to be listed, FALSE otherwise
	36-40	TRUE if the AC generator frequency with correction calculations is to be listed, FALSE otherwise.
	41-45	TRUE if the true AC generator frequency is to be listed, FALSE otherwise.
	46-50	TRUE if calibration parameters are to be punched also, FALSE otherwise.
	51-55	TRUE if card images are to be listed as punched, FALSE otherwise (only valid when preceding entry is TRUE)
	56-60	TRUE if ζ and η are known for 541F tube, FALSE otherwise.
	61-65	TRUE if ζ and η are known for 541A tube, FALSE otherwise.
Card 5	6 columns	Wave lengths at which calibration is desired. The number of wave lengths should match the third entry on card 1.

The compute option pertains to the least squares curvefitting procedure that it utilized in the program. If the option variable is 1, then only the curvefitting portion of the procedure is used. However, if the option variable is different from 1, the following actions take place

Option variable	Action
2	Standard deviation is calculated and printed.
3	Standard deviation is calculated and printed, data lying outside a specified number of standard deviations is discarded, the curvefitting procedure is again entered and standard deviation is calculated using this new data.
4	Same as 2 except that the input data is listed.
5	Same as 3 except that both sets of input data to the curvefitting procedure are listed.

If enough previous runs of the program have given a good indication of the value of ζ and η for either or both PM tubes, this data can be introduced for subsequent runs to eliminate the calculation of these quantities. This is capable of decreasing the computer time necessary for a complete run. The program is written to utilize a minimum of memory and has the feature that at specified intervals (specified by the first entry on card 2) of dumping all information in the computer that is necessary to restart the program if the machine malfunctions at a later time. Data processor and input-output times are calculated and printed as the last item in the output. Past experience indicates that approximately 300 seconds are required for each tube at a given wave length assuming that ζ and η are not known.

The digital input tape that is required for this program has to be converted like the other tapes that are received from Telecomputing Services, Inc. This problem as well as some other pertinent ones will be covered in the general section of data reduction.

Stratosphere Chamber Tests

Prior to the launching of the balloon, the spectro-photopolarimeter was tested in the Stratosphere Chamber at Holloman Air Force Base*. The chamber is approximately 8 ft. wide, 12 ft. deep, and 10 ft. high and is capable of simulating pressure and temperature to an altitude of 200,000 feet. The purpose of the test was to check the entire operation of the spectrophotopolarimeter under simulated pressure and temperature conditions experienced in an actual balloon flight, and especially to test the new pointing control amplifier, since the previous amplifier had failed when it became cold on the 26 August 1964 flight. Three separate tests, conducted on 17 June 1965, 18 June 1965, and 22 June 1965, were necessary

*Environmental Test Branch, Guidance and Control Directorate, Deputy for Guidance Test, Air Force Missile Development Center, Holloman Air Force Base, New Mexico.

before reasonable confidence could be placed in the system.

The altitude and the temperature are programmable, but since one of the cooling pumps had broken down at the time of the tests, the altitude and temperature profiles do not follow a standard atmosphere. The facilities at the Stratosphere Chamber include the capability of measuring at least 10 temperatures via thermocouples plus six temperatures which the Environmental Test Branch personnel use to measure the temperature at different parts on the chamber; a Data Logger, which prints these temperatures at a predetermined time interval; and numerous power and coax feed-throughs into the chamber for connecting power and obtaining signals. One serious difficulty was encountered, however, and this was the unavailability of a suitable light source inside the chamber to simulate the sun. Since the pointing control amplifier and system were to be checked, this developed into a serious handicap.

Power was supplied through the feed-throughs from a Kepco KS36-10M power supply, and the input to the telemetry subcarriers was brought outside through the coax connectors. Telemetry was not turned on during any of the tests, and, in retrospect, this was a mistake.

Thermocouples were placed in the following locations:

1 Main battery box - on metal
2 Intervalometer box
3 Control box
4 Pointing control elevation deck
5 Pointing control azimuth deck
6 Telemetry and electronics battery box - on the lid
7 Telemetry and electronics battery box - on the side
8 Gondola frame
9 Azimuth servo drive mechanism
10 Pointing control amplifier case - on top

In addition, Environmental Test Branch personnel monitored the temperature in the following locations:

1 South wall
2 Floor
3 Ceiling
4 North wall
5 Door
6 Air - approximately 6" from south wall

During the first test (17 June 1965), insufficient data was available to ascertain the cause of the pointing control failure. The sun simulator, five infrared lamps mounted on a plywood board, provided too broad a source to actually test the proper operation of the pointing control. However, it was thought that the pointer had actually lost the "sun" although the direct reason was not known. The temperature designated as the pointing control elevation deck during this test was taken at the output transistors (2N1716) heat sink, while that designated as the pointing control azimuth deck was obtained from the input transistors (2N338) head sink.

For the second test, besides the telemetry signals, the input signals to the pointing control amplifier were brought out of the chamber. This permitted an external signal to be supplied to the amplifiers in order to check their operation. Also, the azimuth clutch leads were brought out so that the clutch current could be measured. Again, the pointing control suffered an apparent loss of gain, which by rough calculations appeared to be approximately a factor of 10 decrease in gain. During this test and the previous test, the friction brake method of damping the azimuth drive was used to prevent unwanted oscillations. Mr. Al Goddard* suggested that this friction brake be removed since it would limit the accuracy of the pointing control, and instead, introduce error-rate damping. This was

*Hi-Altitude Instrument Company, 1560 S. Otus Street, Denver, Colorado 30226.

accomplished by the incorporation of sufficiently large tantalytic capacitors to decrease the amount of inverse feedback for an AC signal. This had the effect of increasing the AC gain of the amplifier while maintaining the DC gain at approximately the same level. Also, the amount of inverse feedback was increased, to decrease the overall gain in order to make the system more stable. For the second test, the two pointing control deck temperatures were measured on the output transistors heat sinks.

The third test was performed to check the modifications that had been made to the system. Although the change in gain with temperature seemed only to be approximately a factor of 3, it was felt that the decrease in system gain coupled with the increase in the sun's relative intensity at float altitude would tend to make the system stable. The pointing control deck temperatures for this test were measured at the input transistors heat sinks.

During all three test, the Ferguson drive mechanism and the quarter wave plate drive seemed to function properly. The electronics in the detector head were not turned on, but the temperature inside the can seemed to be maintained by the heaters at the proper temperature.

Reproductions of the Data Logger output and the temperature-altitude profiles are reproduced in figures 45 through 50. The check point on the data Logger is a thermocouple mounted inside the Data Logger electronics which serves as a check on the system, although its temperature is not maintained at any one value.

A reproduction of the test event report is reproduced in Appendix B.

Data Reduction and Analysis

Since the mathematics involved in the data reduction for this project

Environmental Test Branch
Guidance and Control Directorate
Deputy for Guidance Test
AIR FORCE MISSILE DEVELOPEMENT CENTER
Holloman Air Force Base, New Mexico
Ultraviolet Spectrometer Simulated Altitude Test
Project 6665 Georgia Tech, Date 17 June 65

TIME	ALT	CK PT	MAIN BOX	INT BOX	CONT BOX	PCEL DECK	PCAZ DECK	TMBAT LID	TMBAT CASE	FRAM	AZ SERV	PC AMP
09:50	004	087	073	077	079	087	083	072	079	060	068	070
10:00	004	088	068	070	073	084	080	057	065	032	052	047
10:10	011	088	064	066	068	080	075	045	053	013	039	034
10:20	017	089	060	061	064	077	071	032	041	-006	027	019
10:30	025	089	058	058	060	074	067	023	032	-018	019	009
10:40	031	090	058	056	057	070	064	016	026	-026	013	001
10:50	037	090	057	054	055	068	061	011	022	-031	009	-002
11:00	043	091	056	053	052	066	059	006	018	-036	007	-006
11:10	051	091	056	052	051	065	058	008	018	-040	006	-009
11:20	059	092	056	052	050	064	057	004	017	-041	007	-009
11:30	064	092	056	051	048	063	056	002	017	-042	007	-010
11:40	068	092	057	052	048	063	055	002	018	-041	010	-009
11:50	082	091	057	052	048	062	055	002	019	-039	013	-009
12:00	087	092	057	052	048	062	055	002	021	-039	014	-009
12:10	094	093	058	053	048	062	055	003	022	-037	017	-008
12:20	102	093	058	053	048	062	055	005	024	-035	020	-007
12:30	108	093	059	054	048	062	055	005	026	-033	022	-006
12:40	116	094	059	055	049	063	056	006	028	-031	024	-005
12:50	118	094	059	055	049	063	056	007	029	-029	026	-003
13:00	123	094	059	055	050	057	056	005	030	-027	026	-009
13:10	122	095	060	056	050	054	055	003	030	-025	026	-011
13:20	123	095	060	056	050	053	054	002	030	-022	026	-012
13:30	120	095	061	056	051	058	054	003	031	-019	028	-006
13:40	121	095	061	057	052	061	055	006	032	-016	030	-002
13:50	121	095	061	058	052	063	056	008	034	-013	032	001
14:00	124	096	061	059	053	064	058	010	036	-011	034	004
14:10	123	096	062	060	054	066	058	011	038	-008	036	007
14:20	121	096	062	061	055	067	060	012	040	-008	037	009
14:25	096	097	064	061	056	069	063	016	041	-005	038	016

Environmental Test Branch
Guidance and Control Directorate
Deputy for Guidance Test
AIR FORCE MISSILE DEVELOPEMENT CENTER
Holloman Air Force Base, New Mexico
Ultraviolet Spectrometer Simulated Altitude Test
Project 6665 Georgia Tech, Date 17 June 65

TIME	ALT	CK PT	MAIN BOX	INT BOX	CONT BOX	PCEL DECK	PCAZ DECK	TMBAT LID	TMBAT CASE	FRAM	AZ SERV	PC AMP
14:30	038	096	060	060	055	067	060	015	041	-004	033	015
14:35	033	096	062	061	056	068	061	014	040	-002	033	017
14:40	029	096	062	062	057	069	062	016	040	001	033	019
14:45	024	096	062	062	058	068	062	019	039	006	034	020
14:50	019	096	063	063	058	069	062	021	039	011	034	022
14:55	014	097	063	063	059	069	062	023	039	015	035	023
15:00	010	097	065	066	060	069	064	025	039	018	035	026
15:05	005	097	063	065	060	069	064	026	038	019	035	027
15:10	004	097	063	065	061	070	064	026	038	019	034	027

Environmental Test Branch
Guidance and Control Directorate
Deputy for Guidance Test
AIR FORCE MISSILE DEVELOPEMENT CENTER
Holloman Air Force Base, New Mexico
Ultraviolet Spectrometer Simulated Altitude Test
Project 6665 Georgia Tech, Date 17 June 65

TIME	ALT	CK PT	SW	FLOR	CEL	NW	DOR	AIR
09:50	004	087	010	015	006	006	023	034
10:00	004	088	-014	002	-016	-017	-004	009
10:10	011	088	-030	-021	-036	-031	-023	-010
10:20	017	089	-041	-033	-048	-044	-037	-027
10:30	025	089	-052	-049	-056	-056	-046	-036
10:40	031	090	-058	-061	-063	-063	-053	-044
10:50	037	090	-064	-069	-068	-068	-060	-049
11:00	043	091	-070	-074	-071	-073	-063	-053
11:10	051	091	-074	-078	-073	-076	-067	-055
11:20	059	092	-077	-081	-074	-080	-069	-059
11:30	064	092	-073	-074	-073	-071	-067	-052
11:40	068	092	-060	-064	-062	-061	-055	-049
11:50	082	091	-057	-063	-062	-058	-058	-047
12:00	087	092	-064	-066	-066	-064	-054	-050
12:10	094	093	-053	-059	-057	-055	-050	-047
12:20	102	093	-050	-055	-053	-051	-045	-045
12:30	108	093	-047	-051	-049	-047	-043	-038
12:40	116	094	-043	-048	-046	-044	-039	-035
12:50	118	094	-040	-045	-044	-041	-037	-034
13:00	123	094	-035	-039	-037	-035	-035	-029
13:10	122	095	-028	-032	-030	-028	-028	-025
13:20	123	095	-021	-025	-023	-021	-022	-020
13:30	120	095	-016	-020	-018	-016	-016	-015
13:40	121	095	-015	-019	-018	-015	-015	-013
13:50	121	095	-013	-017	-016	-014	-013	-012
14:00	124	096	-012	-016	-015	-012	-012	-010
14:10	123	096	-008	-012	-010	-008	-009	-007
14:20	121	096	-018	-020	-025	-019	-021	-012
14:25	096	097	-020	-023	-023	-020	-016	-003

Environmental Test Branch
Guidance and Control Directorate
Deputy for Guidance Test
AIR FORCE MISSILE DEVELOPEMENT CENTER
Holloman Air Force Base, New Mexico
Ultraviolet Spectrometer Simulated Altitude Test
Project 6665 Georgia Tech, Date 17 June 65

TIME	ALT	CK PT	SW	FLOR	CEL	NW	DOR	AIR
14:30	038	096	-012	-017	-013	-011	-012	-011
14:35	033	096	-015	-017	-019	-015	-014	-009
14:40	029	096	-017	-021	-022	-018	-016	-003
14:45	024	096	-016	-021	-018	-017	-010	005
14:50	019	096	-012	-018	-013	-013	-006	011
14:55	014	097	-008	-015	-010	-009	-002	016
15:00	010	097	-005	-012	-006	-006	000	018
15:05	005	097	-002	-009	-004	-003	003	018
15:10	004	097	001	-007	-001	-000	008	017

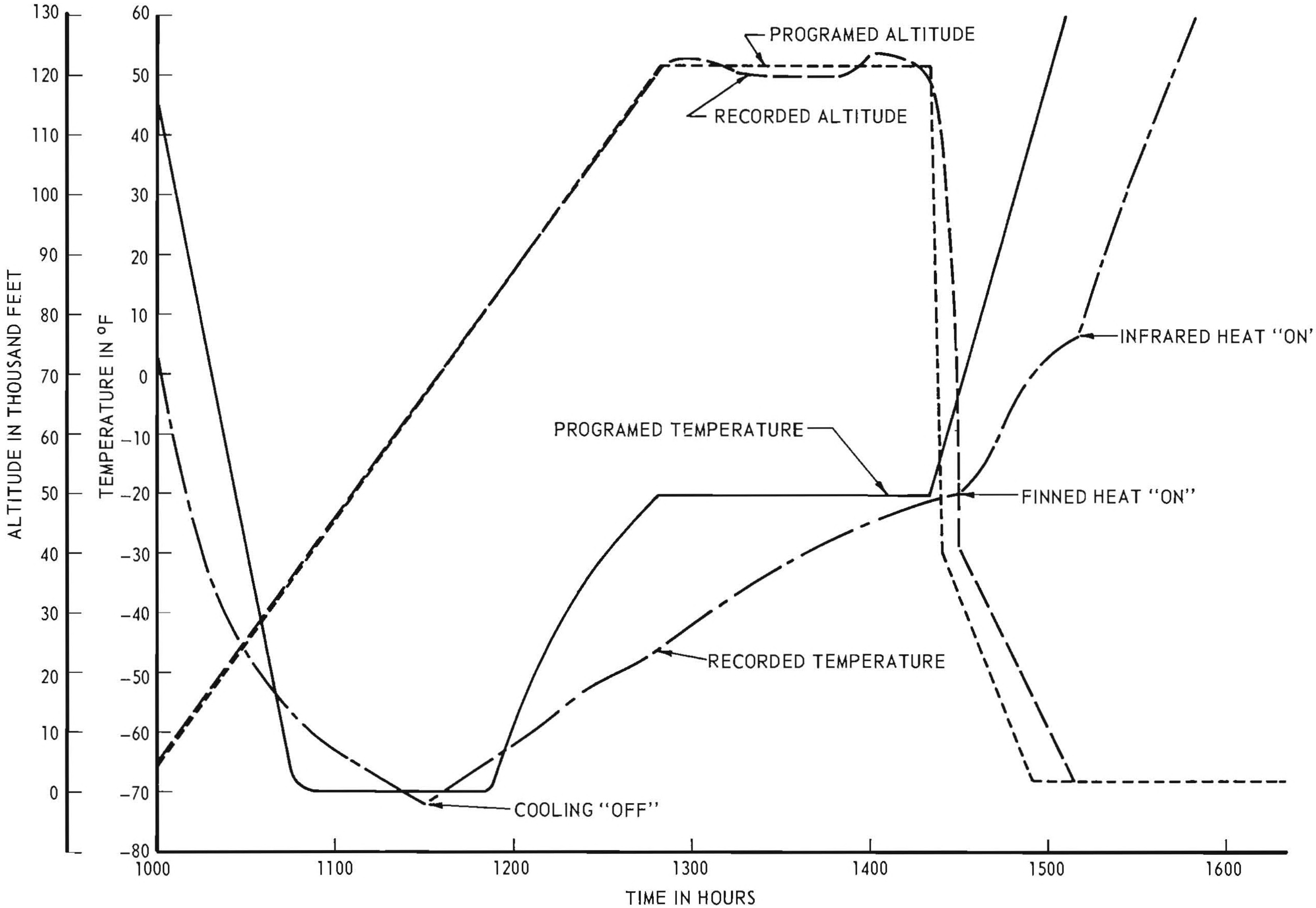

Figure 46. Simulated Altitude Test June 17, 1965.

Environmental Test Branch
Guidance and Control Directorate
Deputy for Guidance Test
AIR FORCE MISSILE DEVELOPEMENT CENTER
Holloman Air Force Base, New Mexico
Ultraviolet Spectrometer Simulated Altitude Test
Project 6665 Georgia Tech, Date 18 June 65

TIME	ALT	DB	DP	CK PT	MAIN BOX	INT BOX	CONT BOX	PCEL DECK	PCAZ DECK	TMBAT LID	TMBAT CASE	FRAM	AZ SERV	PC AMP
10:30	003	076	:::	088	083	084	084	089	088	086	086	085	086	088
10:40	003	007	-05	088	063	075	073	087	088	067	076	055	067	055
10:50	010	-015	-27	088	060	068	070	084	084	044	061	025	050	041
11:00	017	-032	-41	089	057	064	066	081	081	031	048	002	037	026
11:10	025	-043	-50	089	055	060	061	077	077	020	038	-011	028	015
11:20	031	-050		090	054	057	058	073	074	013	030	-021	021	007
11:30	037	-055		090	054	056	056	071	072	006	025	-027	017	001
11:40	042	-060		091	053	054	054	069	070	002	021	-032	013	-002
11:50	051	-063		091	054	054	052	067	068	-000	018	-036	011	-006
12:00	058	-067		092	053	051	050	066	066	001	017	-040	009	-013
12:10	073	-072		092	053	052	049	065	066	001	017	-041	010	-011
12:20	079	-072		093	054	053	048	065	066	000	017	-040	011	-011
12:30	087	-066		093	054	053	048	064	065	-000	018	-038	013	-011
12:40	093	-059		093	055	054	048	064	065	-001	019	-037	015	-011
12:50	100	-053		093	056	054	048	064	065	-001	021	-035	017	-010
13:00	107	-047		094	057	055	048	064	065	-000	023	-032	021	-009
13:10	115	-044		094	057	055	048	064	065	-000	025	-030	023	-007
13:20	123	-042	-50	093	057	054	048	064	065	-000	026	-028	025	-006
13:30	121	-042	-47	094	057	054	049	064	065	-000	028	-026	026	-005
13:40	035	-040	-41	094	056	055	050	064	065	-005	027	-022	022	-007
13:50	026	-032	-15	093	058	058	051	064	065	002	025	-011	023	-005
14:00	016	013	:::	095	062	061	054	064	065	011	026	008	026	004
14:10	007	029	12	094	065	065	058	066	066	022	029	024	032	017
14:20	004	039	16	095	067	068	062	068	069	029	034	033	036	027
14:30	004	050	23	095	071	072	066	072	072	041	043	044	045	043
14:40	004	052	29	095	075	076	071	074	074	052	051	057	054	054
14:50	004	070	34	096	076	078	073	078	077	059	056	065	060	059
15:00	004	079	38	096	080	081	077	083	082	068	063	074	068	067
15:10	004	080	40	095	080	082	079	084	084	072	070	077	073	073

Environmental Test Branch
Guidance and Control Directorate
Deputy for Guidance Test
AIR FORCE MISSILE DEVELOPEMENT CENTER
Holloman Air Force Base, New Mexico
Ultraviolet Spectrometer Simulated Altitude Test
Project 6665 Georgia Tech, Date 18 June 65

TIME	ALT	DB	DP	CK PT	SW	FLOR	CEL	NW	DOR	AIR
10:30	003	076	:::	088	085	083	085	086	085	077
10:40	003	007	-05	088	-020	033	-013	-013	015	021
10:50	010	-015	-27	088	-033	-016	-033	-031	-018	-005
11:00	017	-032	-41	089	-041	-028	-043	-037	-034	-020
11:10	025	-043	-50	089	-051	-041	-053	-055	-045	-031
11:20	031	-050		090	-059	-056	-060	-063	-053	-039
11:30	037	-055		090	-065	-067	-065	-069	-080	-045
11:40	042	-060		091	-070	-073	-069	-073	-064	-049
11:50	051	-063		091	-074	-078	-072	-077	-069	-054
12:00	058	-067		092	-080	-079	-073	-079	-075	-060
12:10	073	-072		092	-071	-074	-061	-071	-059	-051
12:20	079	-072		093	-060	-066	-052	-058	-041	-048
12:30	087	-066		093	-056	-059	-055	-056	-050	-048
12:40	093	-059		093	-049	-052	-049	-049	-046	-044
12:50	100	-053		093	-045	-047	-045	-044	-042	-045
13:00	107	-047		094	-041	-043	-041	-040	-038	-035
13:10	115	-044		094	-038	-039	-037	-037	-035	-031
13:20	123	-042	-50	093	-037	-038	-036	-036	-035	-031
13:30	121	-042	-47	094	-035	-036	-035	-034	-032	-029
13:40	035	-040	-41	094	-031	-032	-030	-030	-028	-024
13:50	026	-032	-15	093	-023	-027	-023	-024	-019	-002
14:00	016	013	:::	095	-017	-021	-016	-018	-007	022
14:10	007	029	12	094	-006	-016	-000	-011	007	034
14:20	004	039	16	095	010	-014	016	002	016	041
14:30	004	050	23	095	027	-009	027	022	035	053
14:40	004	052	29	095	040	-004	037	036	048	065
14:50	004	070	34	096	048	001	044	043	056	074
15:00	004	079	38	096	056	007	052	051	067	083
15:10	004	080	40	095	063	012	060	059	071	083

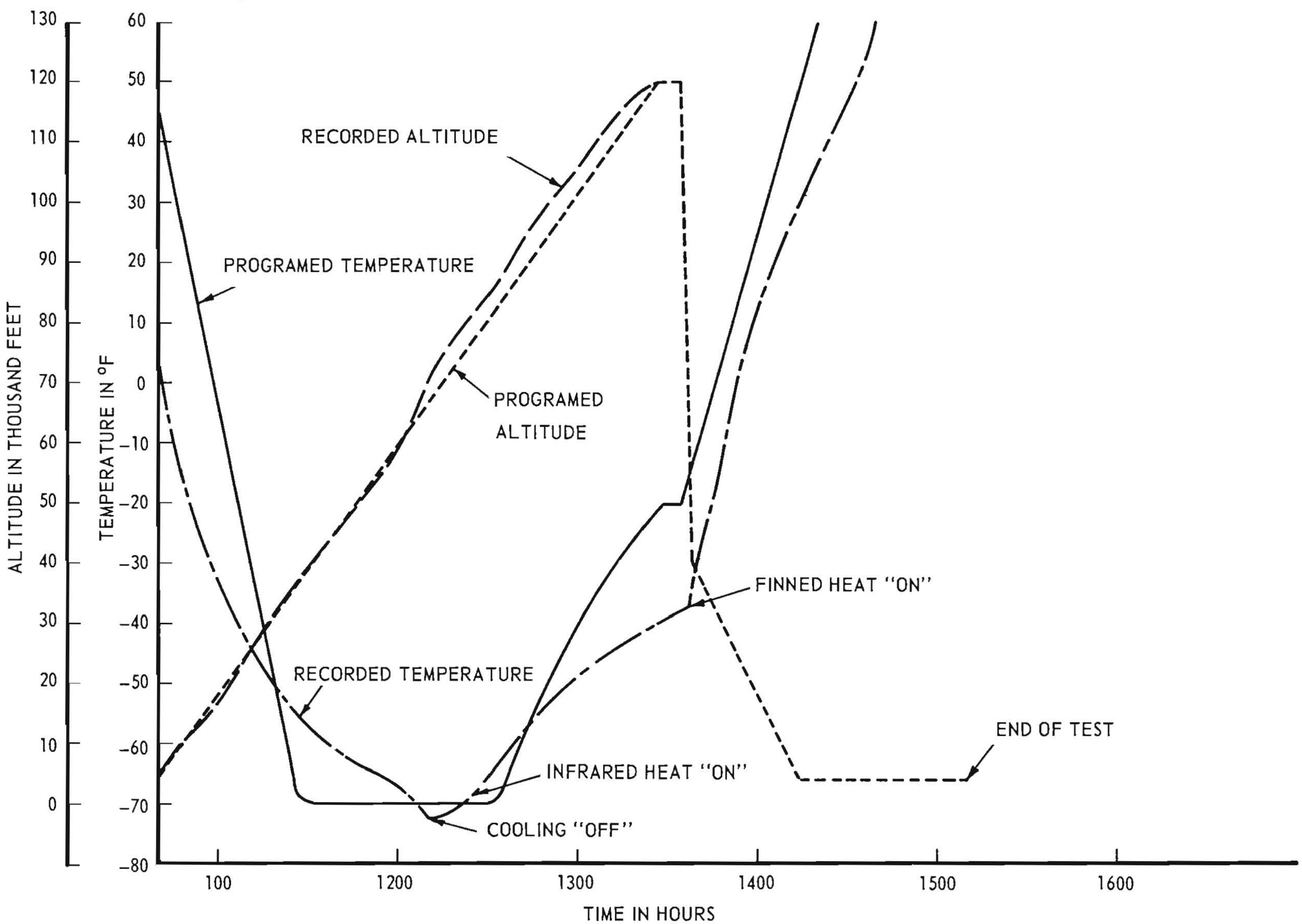

Figure 48. Simulated Altitude Test June 18, 1965.

Environmental Test Branch
Guidance and Control Directorate
Deputy for Guidance Test
AIR FORCE MISSILE DEVELOPEMENT CENTER
Holloman Air Force Base, New Mexico
Ultraviolet Spectrometer Simulated Altitude Test
Project 6665 Georgia Tech, Date 22 June 65

TIME	ALT	DB	DP	CK PT	MAIN BOX	INT BOX	CONT BOX	PCEL DECK	PCAZ DECK	TMBAT LID	TMBAT CASE	FRAM	AZ SERV	PC AMP
09:20	004	074	:::	085	080	080	081	082	082	085	084	082	084	086
09:30	004	005	00	085	065	073	072	081	080	076	076	058	071	061
09:40	010	-020	-32	085	059	065	068	076	077	055	060	023	054	041
09:50	017	-036	-46	085	055	059	063	071	073	020	046	-000	041	025
10:00	024	-046		085	053	056	059	067	068	029	036	-013	031	014
10:10	031	-054		085	052	054	055	063	065	020	028	-023	023	006
10:20	037	-059		086	051	052	053	060	062	013	022	-030	018	000
10:30	042	-064		087	052	050	051	058	060	008	017	-035	013	-004
10:40	051	-066		087	052	049	049	056	058	004	014	-038	010	-008
10:50	057	-068		088	052	048	048	055	056	000	011	-042	008	-011
11:00	063	-070		088	052	048	046	054	056	000	012	-043	009	-013
11:10	070	-066		088	053	047	045	053	055	-000	013	-042	009	-013
11:20	077	-060		089	054	048	045	053	055	-002	014	-040	011	-014
11:30	083	-056		089	055	048	045	052	054	-002	016	-038	013	-013
11:40	089	-055		089	055	048	045	052	054	-003	017	-036	015	-012
11:50	095	-048		090	056	048	045	053	054	-003	019	-034	017	-011
12:00	102	-044		090	057	048	046	053	055	-003	021	-032	019	-010
12:10	034	-037	-46	090	054	048	046	053	055	-006	020	-029	017	-012
12:20	025	-015	-22	090	059	054	049	055	055	-000	023	-013	021	-000
12:26	019	-009	-24	090	059	054	050	055	056	003	024	-005	022	004
12:30	015	-009	-16	070	060	056	052	056	057	006	025	001	024	008
12:40	005	004	-03	091	062	060	055	058	059	013	029	014	027	017
12:50	004	010	00	091	062	061	057	059	060	017	030	017	029	021

Environmental Test Branch
Guidance and Control Directorate
Deputy for Guidance Test
AIR FORCE MISSILE DEVELOPEMENT CENTER
Holloman Air Force Base, New Mexico
Ultraviolet Spectrometer Simulated Altitude Test
Project 6665 Georgia Tech, Date 22 June 65

TIME	ALT	DB	DP	CK PT	SW	FLOR	CEL	NW	DOR	AIR
09:20	004	074	:::	085	084	082	084	085	081	083
09:30	004	005	00	085	-011	011	-014	-013	014	019
09:40	010	-020	-32	085	-033	-020	-038	-034	-024	-011
09:50	017	-036	-46	085	-042	-028	-048	-044	-038	-025
10:00	024	-046		085	-051	-041	-055	-055	-048	-035
10:10	031	-054		085	-059	-054	-062	-063	-055	-041
10:20	037	-059		086	-066	-064	-067	-069	-062	-048
10:30	042	-064		087	-071	-070	-070	-073	-066	-052
10:40	051	-066		087	-076	-075	-073	-077	-070	-055
10:50	057	-068		088	-078	-078	-075	-080	-073	-060
11:00	063	-070		088	-071	-071	-071	-072	-067	-056
11:10	070	-066		088	-060	-061	-060	-080	-059	-053
11:20	077	-060		089	-054	-055	-054	-053	-052	-050
11:30	083	-056		089	-050	-051	-050	-049	-048	-046
11:40	089	-055		089	-047	-047	-047	-046	-045	-045
11:50	095	-048		090	-044	-045	-044	-042	-042	-043
12:00	102	-044		090	-040	-040	-039	-038	-039	-038
12:10	034	-037	-46	090	-037	-038	-039	-037	-035	-030
12:20	025	-015	-22	090	-029	-034	-029	-029	-022	-006
12:26	019	-009	-24	090	-019	-026	-019	-019	-013	002
12:30	015	-009	-16	070	-013	-020	-013	-013	-007	008
12:40	005	004	-03	091	-001	-009	-002	-001	004	017
12:50	004	010	00	091	003	-003	002	003	008	019

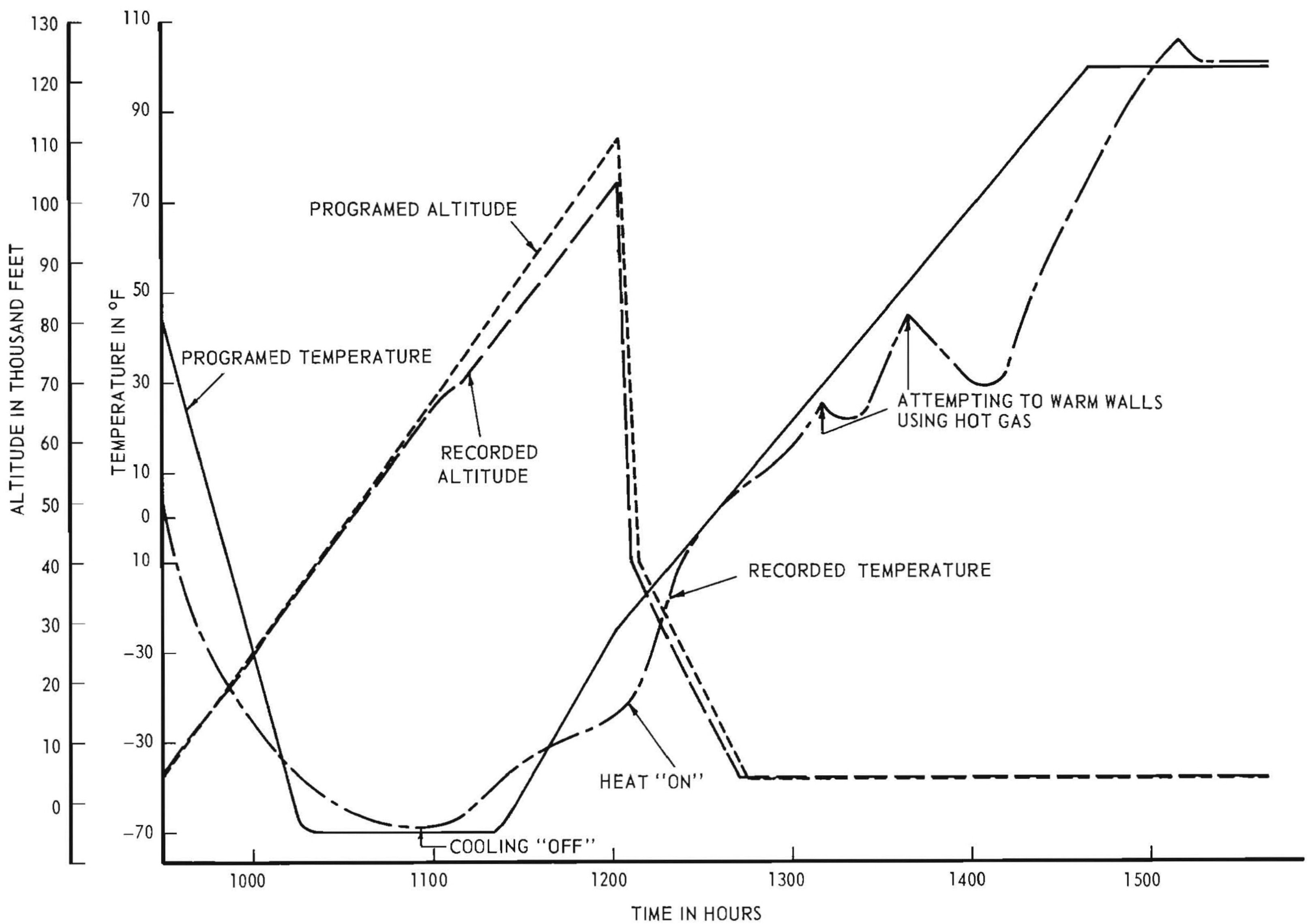

Figure 50. Simulated Altitude Test June 22, 1965.

is fairly straightforward, the basic problem stems from the large volume of data that is accumulated. Digital computers seem to be a feasible solution to the problem, so considerable work was done prior to the flight in writing, trouble-shooting, and testing computer programs. The large amount of data that is generated by the experiment is due to the fact that simultaneously four quantities must be known: the position of the grating, the angular position of the rotating retardation plate, and the two currents from the photomultiplier tubes. Since there is an 80 cps component to the two photomultiplier tube signals, samples must be taken with a high enough frequency to sufficiently recreate this 80 cps signal. Thus the four required signals are digitized at a rate of 500 samples per second, which corresponds to approximately 60 degrees of rotation of the retardation plate between successive samples. Besides the four channels mentioned above, the commutated channel is also digitized, but the rate here depends on the frame time of the commutator and each commutator segment is digitized only once per frame.

The analog to digital conversion is accomplished at Holloman Air Force Base by Telecomputing Services, Inc.* The raw data tape which was recorded at the ground telemetry site by Land-Air, Inc. is sent to TSI for data reduction. Limitations on the digitizing facilities require a maximum of 1000 samples total per second; therefore, two passes had to be made in order to accomplish the 500 sample per second per channel rate that is necessary. The commutated channel is first passed through the decommutator and then digitized. Thus for any instant in time, there are three tapes

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*Telecomputing Services, Inc., Box 447, Holloman Air Base, New Mexico, Mr. Cal Skelton, Test Analysis Section.

which contain the information: two data tapes containing the four FM/FM channels, and one tape containing the PAM/FM/FM data.

The data reduction process from this point proceeds in stages. The first problem is the conversion of word length from the IBM 7094 word length of 36 bits from TSI to the B-5500 word length of 48 bits of Georgia Tech. The next step would be the calculation of wave length or position of grating. The following step would then be the calculation of the various segments on the commutator, and the final step would be the calculation of the Stokes vector of the incident light at any particular time.

The computer programs which perform these various stages are written in Algol-60 with the programming concept that they should be more general than specific in their application, i.e. if a minor change is made, say, the number of words per block on the tape is changed, this should not necessitate any major change in the program. Incidentally, the number of words per block on the tape is automatically accounted for during the execution of the programs, so that the programmer does not even have to know in advance the number, or as the case is on the commutator tape, a variable number of words can be handled without difficulty.

The programs are as follows:

FM Data Converter Program

This program basically converts the IBM 7094 digital tape generated by TSI into a digital tape which is usable on the Georgia Tech's Burroughs B-5500 computer. The tapes are in the same format except that the 7094 word length is 36 bits, while that of the B-5500 is 48 bits. The program accepts as input the two tapes containing the four digitized channels of FM/FM data and produces one tape containing all four channels. (At the present time, the digital tapes generated by TSI are written in low density -- 200 bits per inch -- on the tape, but this is not a limitation for the B-5500, which can read in either low or high density). The flow diagram for this program is shown in figure 51, while the reproduced Algol deck is shown in Appendix C.

The program has as its input:

(1) FILE FIL1, in free field format, whether this is a test or run, the interval between records which are listed, the number or records at each interval to be listed, the number of pairs of input tapes (maximum 3), and the number of blocks or records to be converted (ignored if it is a production run).

(2) FILE FFMD1, tape unit unlabeled tape, the digital tape from TSI containing the 10.5 KC and 22.0 KC subcarriers.

(3) FILE FFMD2, tape unit, unlabeled tape, the digital tape from TSI containing the 30.0 KC and the 40.0 KC subcarriers.

(4) FILE FFMD3, same as (2)

(5) FILE FFMD4, same as (3)

(6) FILE FFMD5, same as (2)

(7) FILE FFMD6, same as (3)

Numbers (4) through (7) are only present if the number of pairs of input tapes is greater than one. An example of an input for FIL1 would be:

0, 20, 5, 1, 100 .

This would tell the computer that it is to be a test run, starting at every 20th block, 5 blocks are to be listed, that there is only 1 pair of input tapes, and to convert only 100 blocks. Another example would be:

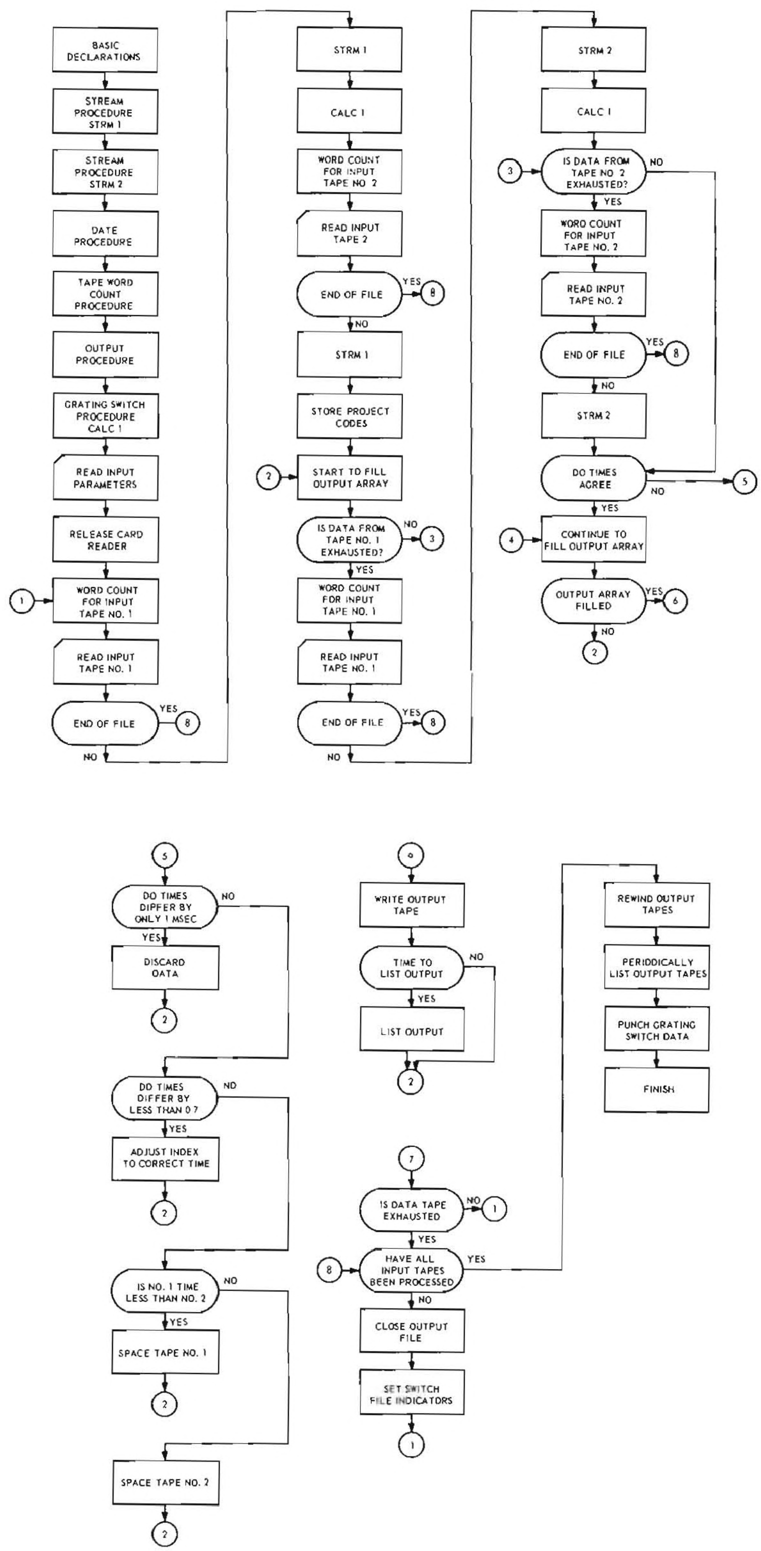

Figure 51. FM Data Converter Program Flow Chart.

1, 250, 1, 2, 0

This would tell the computer that 1 is a production run, every 250th block is to be listed, that there are two pairs of input tapes, and the last number is ignored but must be present.

The program has as its output:

(1) FILE FIL2, line printer, a listing of the data as it is converted, and then after the tape is rewound, a listing at the proper interval of the output tape.

(2) FILE ZZZZZ01, labeled tape, a digital tape containing data, time, and multiplex number in a packed-word concept from the 1st pair of input tapes.

(3) FILE ZZZZZ02, same as (2) except from the 2nd pair of input tapes.

(4) FILE ZZZZZ03, same as (2) except from the 3rd pair of input tapes.

One block on the output tape contains $\frac{1}{2}$ second of data, thus permitting easy positioning of the tape at a desired time. The data is stored on the output tape and the input tape in what is known as a packed word, i.e., one computer word contains more than one word of information. The tapes as they are received from TSI are written in the following format:

Bits	0-10	Data
	11-18	Time in seconds (maximum of 255)
	19-28	Time in milliseconds
	29-35	Multiplex number

The multiplex number is a number assigned by TSI to designate from which subcarrier the data was obtained. (On the commutated data tape, this number designates the segment from which the data is obtained.)

The output tape(s) are written in the following format:

Bits	0	Unused
	1-13	Wave length (to be added later)

```
COMMENT -- FM DATA CONVERTER PROGRAM (ADDITION OF WAVELENGTH)              ;
BEGIN INTEGER I,J,L,N,SN,FL,TPI,TPO,BLK,INTP,LBLK                          ;
      REAL TM, LAMBDA                                                      ;
      ARRAY T[0:25,0:30,0:4], LMB[0:4], STT,STP[0:25]                      ;
      ALPHA ARRAY A[0:1022]                                                ;
      INTEGER ARRAY SCAN[0:40]                                             ;
      LABEL L1,L2,L3,L4,L5                                                 ;
      BOOLEAN Z                                                            ;
      FILE IN  FIL3 (5,10),
               TSI04 (1,1010),
               TSI05 (1,1010)                                              ;
      FILE     FMDATA4 2 "FMDATA" "FILE4" (1, 1010, SAVE 365),
               FMDATA5 2 "FMDATA" "FILE5" (1, 1010, SAVE 365)              ;
      SWITCH FILE SWIN ← TSI04, TSI05                                      ;
      SWITCH FILE SWOUT ← FMDATA4, FMDATA5                                 ;
      FILE OUT FIL2 6 (5,15)                                               ;
      FORMAT OUT FMT1 (2(I8, X8), I5),
                 FMT2 (4(I4,".0",X1,I2,X1,I3,".",I3,X1,I4,".0",X3),I4),
                FMT3 (I2," HOURS",I3," MINUTES",I3," SECONDS", X10,
                      "TIME ", I6)                                         ;
FORMAT OUT FMTA (4(I10,X10))                                               ;
      PROCEDURE OUT3 (A, N, F1)                                            ;
           VALUE N                                                         ;
           INTEGER N                                                       ;
           ARRAY A[0]                                                      ;
           FILE F1                                                         ;
BEGIN INTEGER I,J,TM,T1,T2,T3                                              ;
      LIST LIST1 (T1,T2,T3,TM),
           LIST2 (FOR I ← 3 STEP 4 UNTIL N-3 DO [FOR J ← 0,1,2,3 DO [
    A[I+J].[1:13],A[I+J].[43:5], A[I+J].[25:8], A[I+J].[33:10], A[I+J].
                 [14:11]], (I+1) DIV 4])                                   ;
```

```
        FOR I ← 1,2 DO                                                  BEGIN
              TM ← A[I].[30:17]                                             ;
              T1 ← TM DIV 3600                                              ;
              T2 ← (TM - 3600×T1) DIV 60                                    ;
              T3 ← TM - 3600×T1 - 60×T2                                     ;
              WRITE (F1, FMT3, LIST1)                                   END ;
        IF (N-3) MOD 4 ≠ 0                                  THEN
              FOR I ← N+1 STEP 1 WHILE (I+N-3) MOD 4 ≠ 0 DO
                   A[I] ← 0                                                 ;
        WRITE (F1, FMT2, LIST2)                                             ;
END                                                                         ;
        PROCEDURE WORD (FILEID, N, LEOF, LPAR)                              ;
              FILE FILEID                                                   ;
              INTEGER N                                                     ;
              LABEL LEOF, LPAR                                              ;
BEGIN STREAM PROCEDURE S (A,B)                                              ;
        BEGIN      SI ← A                                                   ;
                   DI ← B                                                   ;
                   SI ← SI - 8                                              ;
                   DS ← WDS                                                 ;
        END                                                                 ;
        READ (FILEID[NO])[LEOF:LPAR]                                        ;
        S (FILEID(0), N)                                                    ;
END                                                                         ;
MONITOR FIL2 (SN, FL) ; %
BEGIN INTEGER I,J,K                                                         ;
        LABEL L1,L2                                                         ;
        FORMAT IN FMT1 (5(F7.2,X3)),
                   FMT2 (2(I4, X6)),
                   FMT3 (X13, F9.3)                                         ;
        LIST LIST1 (FOR I ← 0,1,2,3,4 DO LMB[I]),
              LIST2 (FOR K ← 0,1,2,3,4 DO T[I,J,K])                         ;
        READ (FIL3, FMT2, INTP, LBLK)                                       ;
        READ (FIL3, FMT1, LIST1)                                            ;
L1:     READ (FIL3, FMT2, I, J)[L2]                                         ;
        READ (FIL3, FMT3, LIST2)                                            ;
```

```
        GO TO L1                                                          ;
L2:     CLOSE (FIL3, RELEASE)                                             ;
END                                                                       ;
        FL ← -1                                                           ;
        TPI ← TPO ← SN ← 0                                                ;
L1:     WORD (SWIN[TPI], N, L3, L1)                                       ;
        READ (SWIN[TPI], N, A[*])                                         ;
        IF TPI = 1                                       THEN
             IF A[1].[30:17] ≥ 68007.0                   THEN
                  GO TO L3                                                ;
        BLK ← BLK + 1                                                     ;
        IF A[0].[18:30] < 10 AND NOT Z                   THEN       BEGIN
             IF FL ≠ -1                                  THEN
                  SCAN[FL] ← SN                                           ;
             SN ← L ← 0                                                   ;
             FL ← FL + 1                                                  ;
OUT3 (A, N, FIL2) ; %TEST PURPOSES ONLY
             IF FL MOD 5 = 0                             THEN       BEGIN
             CLOSE (SWOUT[TPO], *)                                        ;
             TPO ← TPO + 1                                          END   ;
             STT[FL] ← A[1].[30:17]                                       ;
             BLK ← 1                                                      ;
             Z ← TRUE                                               END
                                                         ELSE
             IF A[0].[18:30] > 100                       THEN
                  Z ← FALSE                                               ;
        STP[FL] ← A[1].[30:17]                                            ;
        A[0].[6:12] ← N                                                   ;
        A[0].[18:6] ← FL + 1                                              ;
        A[0].[24:12] ← SN + 1                                             ;
        A[0].[36:12] ← BLK                                                ;
        IF A[2].[30:17] < T[FL,SN,0] - 1.0               THEN       BEGIN
             WRITE (SWOUT[TPO], N, A[*])                                  ;
             GO TO L1                                               END   ;
        FOR I ← 4 STEP 4 UNTIL (IF BLK=1 THEN N-3 ELSE N-1) DO      BEGIN
             TM ← A[2].[30:17] - A[3].[25:8] + A[I].[25:8] + A[I].[33:10]/
```

```
                            1000                                          ;
        IF TM < T[FL,SN,0]                               THEN
            GO TO L2                                                      ;
        IF T[FL,SN,L] ≠ T[FL,SN,L+1]                     THEN
        LAMBDA ← LMB[L] + (TM-T[FL,SN,L])×(LMB[L+1]-LMB[L])/
                   (T[FL,SN,L+1]-T[FL,SN,L])                              ;
        FOR J ← -1,0,1,2 DO
            A[I+J].[1:13] ← ENTIER (LAMBDA+0.5)                           ;
        IF TM > T[FL,SN,L+1]                             THEN  BEGIN
            L ← L + 1                                                     ;
            IF L ≥ 4                                     THEN  BEGIN
                IF T[FL,SN+1,0] = 99999.999              THEN  BEGIN
                    WHILE A[0].[18:30]>10 DO
                         READ (SWIN[TPI], 1, A[*])[L3:L1]                 ;
                    SPACE (SWIN[TPI], -1)                                 ;
                    GO TO L1                                   END        ;
                L ← 0                                                     ;
                SN ← SN + 1                                    END        ;
                                                               END        ;
L2:                                                                 END   ;
    IF BLK MOD LBLK = 0                                  THEN
        OUT3 (A, N, FIL2)                                                 ;
    WRITE (SWOUT[TPO], N, A[*])                                           ;
    GO TO L1                                                              ;
L3: SCAN[FL] ← SN                                                         ;
    A[0] ← 0                                                              ;
    REWIND (SWIN[TPI])                                                    ;
    TPI ← TPI + 1                                                         ;
    IF TPI < INTP                                        THEN
        GO TO L1                                                          ;
    WRITE (FIL2[PAGE])                                                    ;
    FOR I ← 0 STEP 1 UNTIL FL DO
        WRITE (FIL2, FMT1, STT[I], STP[I], SCAN[I])                       ;
END .
```

14-24	Data
25-32	Time in seconds
33-42	Time in milliseconds
43-47	Multiplex number

The record on the output tape is in the following form:

1st word	Bits	6-17	Number of words in the block
	Bits	18-23	File number corresponding to TSI tape file
	Bits	24-35	The number of the wave length scan
	Bits	36-47	Block number
2nd word	Bits	30-46	High order time from 1st tape (seconds of day)
3rd word	Bits	30-46	High order time from 2nd tape (should agree with 2nd word)
4th word on			Data in the packed word concept

On the first record on the tape, two additional words are placed after the ones described above. These are the project codes derived from the TSI input tapes. These are placed at the end of the record so that the first portion of all the records would be identical. Since a large number of output tapes will be generated, it is anticipated that a label equation card would be used to equate the output files (ZZZZZ01, ZZZZZ02, and ZZZZZ03) to some other identifier. A label equation card equates the file identifier which is used in the program to a file identifier which will be read off an input file or written on an output file. The wave length calculation program is shown in figure 52.

Commutator Converter Program

This program differs slightly from the data conversion program in that it will only accept a single tape at a time as input. However, the basic logic is the same, and the output formats have similarities. The program converts the IBM 7094 data tape generated by Telecomputing Services, Inc. from a 36 bit word length to a 48 bit word length for use on the B-5500. The flow diagram is shown in figure 53, while the reproduced Algol deck is shown in figure 54. The program converts the word length and lists on the line printer periodically the tape block which is currently being written, and when the input data tape is exhausted, the output tape is rewound and periodically listed to serve as a check on the conversion process. During the listing of the output tape, the project code is written prior to the first block. It has been our experience that TSI identifies each of their tapes with a different project code (by changing the last two digits). Therefore, if any confusion should arise about identification of the tape, the project code is available from the listing.

The program has as its input:

(1) FILE FIL1, in free field format, the total number of blocks to be processed, the interval between the records which are to be listed, and the number of files on the input tape.

(2) FILE FCMU, tape unit, unlabeled tape, the digital tape from TSI containing the commutated data.

If the entire tape is to be processed, the number of blocks to be processed is a number in excess of the number of blocks on the tape. There are usually around 5000 blocks on a tape, so as input, the number of blocks to be processed is conveniently placed at 99999999.

The program has as its output:

(1) FILE FIL2, line printer, a listing of the data as it is converted at the interval specified by the input data on FIL1, and after the tape has been rewound, a listing, again at the proper interval, of the output tape. During the conversion process, when an end-of-file condition occurs on the input tape, the program writes the last block read of one file and the first block of the next file, but does not change the file identifier of the output file.

(2) FILE FDTC1, labeled tape, a digital tape written in the packed-word concept, containing a single file with all the input data included.

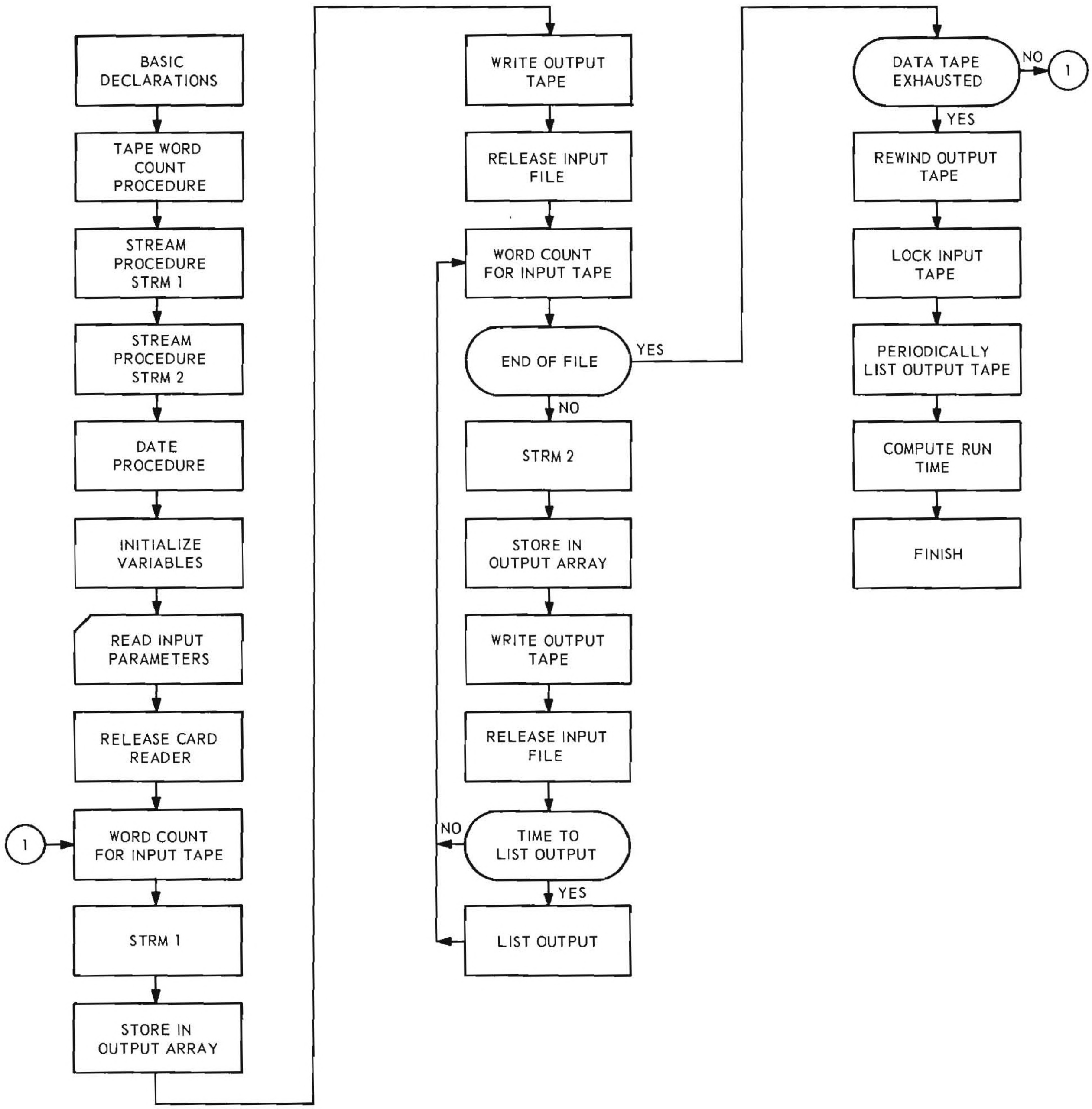

Figure 53. Commutator Converter Program.

```
COMMENT -- COMMUTATOR CONVERTER PROGRAM                                     ;
BEGIN INTEGER I,J,K,M,N,K1,K2,PROJCODE,BLOCK,P, IFIL, IFIL1,TS              ;
      REAL RNTIM, RNTIM1                                                    ;
      LABEL L1, L2, L3, L4, L0                                              ;
      SAVE ARRAY A[0:500]       ; ALPHA ARRAY B[0:600]                      ;
      ARRAY U[0:250]                                                        ;
STREAM PROCEDURE TST1(A,B)); BEGIN SI←A;DI←B;SI←SI-8;DS←8 CHR END           ;
STREAM PROCEDURE STRM1(A,B,I,J,K));VALUE I,J,K;BEGIN SI←A;DI←B;SI←SI+2;DI
←DI+4;DS←4 CHR;DI←DI+5;DS←3 CHR;SI←SI+3;I(J(DI←DI+2;DS←6 CHR));K(DI←DI+2
;DS←6 CHR) END;STREAM PROCEDURE STRM2(A,B,I,J,K));VALUE I,J,K;BEGIN SI←A;
DI←B;DI←DI+5;DS←3 CHR;SI←SI+3;I(J(DI←DI+2;DS←6 CHR));K(DI←DI+2;DS←6 CHR)
END;PROCEDURE OUT1(A,N,FILEID));VALUE N;INTEGER N;FILE FILEID;ALPHA ARRAY
 A[0];BEGIN INTEGER I,J,TM,THR,TMIN,TSEC;ARRAY B[ 1:12];FORMAT OUT FMT1(
I2, " HOURS", I3, " MINUTES",I3, " SECONDS",X10,I10,X45,"BLOCK NUMBER ",
I8),FMT2(4(F3.0,X1,F8.3,X1,F7.1,X9        )));FOR I←1   DO BEGIN TM←A[I]
.[30:17];THR←TM DIV 3600;TMIN←(TM-3600×THR) DIV 60;TSEC←TM-3600×THR-60×T
MIN;WRITE(FILEID,FMT1,THR,TMIN,TSEC,TM,A[0])END;FOR I←3 STEP 4 UNTIL N
 DO BEGIN FOR J←0 STEP 1 UNTIL 3 DO BEGIN
IF (I+J)>N THEN A[I+J]←0;
                                          B[3×J+1]←A[I+J].[43:5]×1.0;B[3
×J+2] ← A[I+J].[25:8]+A[I+J].[33:10]/1000;B[3×J+3]←A[I+J].[14:11]×1.0
                            END;WRITE(FILEID,FMT2,FOR J←1 STEP 1 UNTIL 12 D
O B[J]) END;END OUT1                                                        ;
      FORMAT OUT FMT0 ("RUN TIME ", F12.5, "SECONDS"),
              FMT1 (X90, "PROJECT CODE ", I8),
              FMT2(X56, "WORD COUNT ",I5)                                   ;
      FILE IN FIL1 (1,10), FCMU (1, 200)                                    ;
      FILE OUT FIL2 1 (1,15)                                                ;
      FILE FDTC1 2 (1,800)                                                  ;
PROCEDURE DATE(FILEID)                                                      ;
      FILE FILEID                                                           ;
```

```
BEGIN ALPHA D ; INTEGER I, DAY, YR                                          ;
      INTEGER ARRAY MO[1:12]                                                ;
      FORMAT OUT FMT("RUN DATE ", I2,"/",I2,"/",I2)                         ;
      FILL MO[*] WITH 31, 28,31,30,31,30,31,31,30,31,30,31                  ;
      D ← TIME(0)                                                           ;
      YR ← 10×D.[18:6] + D.[24:6]                                           ;
      DAY ← 100×D.[30:6] + 10×D.[36:6] + D.[42:6]                           ;
      I ← 0                                                                 ;
      FOR I ← I+1 WHILE (DAY > 0) DO                                   BEGIN
           DAY ← DAY - MO[I]                                                ;
           IF ((YR MOD 4) = 0) THEN IF (I=2) THEN DAY←DAY-1            END  ;
      DAY ← DAY + MO[I]                                                     ;
      I ← I - 1                                                             ;
      WRITE(FILEID, FMT, I,DAY, YR)                              END   DATE ;
      RNTIM ← TIME(2)                                                       ;
      DATE(FIL2)                                                            ;
      IFIL ← 0                                                              ;
      BLOCK ← 0                                                             ;
      READ (FIL1, /,     M, P, IFIL1)                                       ;
      CLOSE (FIL1, RELEASE)                                                 ;
LO:   READ (FCMU[NO],    1, U[*])                                           ;
      TST1 (FCMU(0), TS)                                                    ;
           N ← 4×((TS   ) DIV 3) + (TS   ) MOD 3                            ;
      WRITE (FIL2[NO], FMT2, N)                                             ;
      K1 ← (N-2) DIV 63                                                     ;
      K2 ← (N-2) MOD 63                                                     ;
      STRM1 (FCMU(0), A[0], K1,63,K2)                                       ;
      FOR I ← N-1 STEP -1 UNTIL 2 DO                                   BEGIN
           B[I+1].[14:29] ← A[I].[12:29]                                    ;
           B[I+1].[43:5] ← A[I].[43:5]                                      ;
           B[I+1].[12:2] ← 0                                           END  ;
      B[2] ← B[1] ← A[1]                                                    ;
      B[N+1] ← A[0]                                                         ;
      B[0] ← BLOCK ← BLOCK + 1                                              ;
      WRITE (FDTC1, N+2, B[*])                                              ;
      OUT1(B, N  , FIL2)                                                    ;
```

```
        RELEASE (FCMU)                                                    ;
L1:     READ (FCMU[NO], 1, U[*])[L2]                                      ;
        TST1 (FCMU(O), TS)                                                ;
             N ← 4×(TS DIV 3) + TS MOD 3                                  ;
        K1 ← (N-1) DIV 63                                                 ;
        K2 ← (N-1) MOD 63                                                 ;
        STRM2 (FCMU(O), A[O], K1,63,K2)                                   ;
        FOR I ← N-1 STEP -1 UNTIL 1 DO                              BEGIN
             B[I+2].[14:29] ← A[I].[12:29]                                ;
             B[I+2].[43:5] ← A[I].[43:5]                                  ;
             B[I+2].[12:2] ← 0                                      END   ;
        BLOCK ←BLOCK + 1                                                  ;
        B[2] ← B[1] ← A[O]                                                ;
        B[O] ← BLOCK                                                      ;
        WRITE (FDTC1, N+2, B[*])                                          ;
        RELEASE (FCMU)                                                    ;
        IF (BLOCK MOD P) = 0                                        THEN
BEGIN
        WRITE (FIL2[NO], FMT2, N)                                         ;
             OUT1 (B, N+1, FIL2)                                          ;
END ;
        IF (BLOCK ≤ M)                                              THEN
             GO TO L1                                                     ;
L2:     IFIL ← IFIL + 1                                                   ;
        WRITE (FIL2[NO], FMT2, N)                                         ;
        OUT1 (B, N+1, FIL2)                                               ;
        IF IFIL < IFIL1 THEN GO TO LO                                     ;
        REWIND (FDTC1)                                                    ;
        LOCK (FCMU, RELEASE)                                              ;
        RNTIM1 ← (TIME(2) - RNTIM)/60                                     ;
        WRITE (FIL2, FMTO, RNTIM1)                                        ;
        READ (FDTC1[NO], 1, U[*])                                         ;
        TST1 (FDTC1(O), N)                                                ;
        READ (FDTC1,N  ,B[*])                                             ;
        PROJCODE ← B[N-1]                                                 ;
        WRITE (FIL2[PAGE]) ;
```

```
        WRITE (FIL2, FMT1, PROJCODE)                                          ;
        SPACE (FDTC1, -1)                                                     ;
        WRITE (FIL2[NO], FMT2, N)                                             ;
        N ← N - 1          ;
L3:     OUT1 (B, N-1, FIL2)                                                   ;
        SPACE (FDTC1, P-1)[L4]                                                ;
        TST1(FDTC1(0), N)                                                     ;
        READ (FDTC1, N   , B[*])[L4]                                          ;
        WRITE (FIL2[NO], FMT2, N)                                             ;
        GO TO L3                                                              ;
L4:     LOCK (FDTC1, RELEASE)                                                 ;
        RNTIM ← (TIME(2) - RNTIM)/60                                          ;
        WRITE (FIL2, FMT0, RNTIM)                                             ;
END .
```

The data is recorded onto FDTC1 in a packed-word which is of the following format:

Bits	0-13	Unused
	14-24	Data
	25-32	Time in seconds
	33-42	Time in milliseconds
	43-48	Multiplex number (commutator segment)

The first word in every record is the block number, and the second word contains the time of day in seconds in bits 30 through 46. The third word on to the end of the record contains the data in the packed-work as mentioned before. On the first record, however, the last word in the record is the project code.

Through a stream procedure, the number of words per record is automatically calculated by the computer. As a tape record is read into the buffer, a word count is generated in the first word prior to the start of the buffer. Thus, by referencing the buffer's starting address and going back one word, the number of words read can be made available to the computer. However, during the reading of the IBM tape, this is the number of 48 bit B-5500 words that are read, and not the number of IBM 36 bit words that are on the tape, thus, the number has to be converted before it is used.

The listing gives the time of day in hours, minutes, and seconds; time of day in seconds; number of words in the block to be listed; and the block number of output tape. If there is insufficient data to finish filling a row, zeroes are placed in the row to complete it.

A label equation should be used if more than one tape is to be generated. Its use has already been described under the FM Data Converter Program. In this case, the label equation card would equate the file identifier which appears in the program, FDTC1, to a file identifier which would be written on the output tape.

With the use of the label equation card, it is believed that changes to the program itself would not be necessary. Therefore, the program was processed by the RECC library SQUEEZE routine for easier handling of the card deck. This program removes all comments and all non-essential spaces from the program, and thereby reduces the number of cards on which the program is written.

Debugging Programs

Two programs have been written to help debug an ailing program or procedure. One of these program lists the blocks inbetween certain specified times, and the other averages the 22.0 KC, 30.0 KC, and 40.0 KC subcarrier oscillators in intervals of 0.1 seconds.

For the averaging program, a listing of which appears in Appendix C, there is no input data. The program was originally designed for looking at the calibration data, and is therefore written for multiple file tape input. The file identifiers used by the program are FLDT2, FLDT3, FLDT1, and FLDT4, in that order. If less than four files are desired, a program change is necessary: the identifier IFIL1 indicates the number of files to be listed; therefore, if only two files are on the tape, IFIL1 should be replaced by 2. If other file identifiers are used, label equation cards which follow the last card in the program (END.) equate the file identifier (including multi-file identifier if one exists) with the respective program file identifiers. For instance, for two files, "MULTI1" "TSI01" and "MULTI1" "TSI02", the identifier IFIL1 should be replaced by 2, and two label equation cards are required equating FLDT2 with "MULTI1" "TSI01" and FLDT3 with "MULTI1" "TSI02".

The other debugging program lists the records on the input tape and requires some input data (see Appendix C). The first card, written in free-field format, indicates the number of pairs of start-stop times desired. The second card (and additional cards, if necessary, also in free-field format) are the starting and stopping times for the listing. The program starts listing at the first block where the high order time is equal to or greater than the starting time, and terminates when the high order time exceeds the stopping time. An example of the input data would be:

```
2,                      (first card)
63168.0, 63168.0,       (second card)
64206.0, 64208.0,       (third card)
```

The listing includes the time, the block number, and the data written in an unpacked form. The information listed for the data includes multiplex number, low order time, data, and wave length. This program is used when it is suspected that bad data exists or if one wishes to observe the input data to ascertain the proper functioning of the programs or procedures.

Summary and Conclusion

It has been shown by two separate flights that the basic design and feasibility of the experiment is satisfactory, although each flight brought to light various flaws in the system. Since insufficient data was taken on each flight, the value of the data that was obtained is somewhat dubious. It is hoped that on the third flight, which is impending in the near future, enough data will be obtained to be of value. The system in its present state is far from being perfect, and numerous improvements could be made to enhance the success of the mission and to protect the instrument during the flight. An obvious improvement would be better shock absorbers for the yoke assembly and extremely reliable impact switches, which would have prevented the serious damage incurred on impact on each of the two flights. The detector head could be improved by better photo-multiplier amplifiers, better calibration circuitry, better high voltage control, and increased dynamic range of the optical-electrical system. A system has already been designed, but at the present is untested, which would perform these functions, and a new type shock cell has already been mounted on the gondola.

No absolute answers have been obtained through the data reduction procedure, and this should probably be accomplished prior to the next flight. However, calibration data has been obtained which demonstrates the feasibility of the system and that the logic of the system insures that answers could be obtained. The calibration program is a more complicated program than the data reduction program, but the two programs follow similar logical sequence; hence, if answers could be obtained from the calibration program, surely they could be obtained from the less complicated data reduction program.

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Appendix A

18 June 1964

Detailed Balloon Flight Required

Project 7621 - Atmospheric Optics (770A) Task 762102
Laboratory - Optical Physics (CRO)
Branch - Atmospheric Optics (CROA)

Flight Title: Ultraviolet Sky Backgrounds

Flight Objective: To measure the spectral distribution of the intensity of natural sky radiation in the 2000 to 4000 Angstroms optical spectrum.

Security Classification: UNCLASSIFIED

Flight Information:

a. Desired Dates of Flight: Aug. 17-31. 1964 period
b. Number of Flights: One(1)
c. Desired Launch Time: One-half to one hour after local sunrise
d. Duration and Altitude: Four-hour float at a maximum altitude, greater than 123,000 ft.
e. Minimum acceptable: One-hour float at 123,000 ft.
f. Ascent Rate requirement: 650 ft/min ± 100 ft/min
g. Release: AFCRL operating site at ARMDC, New Mexico
h. Balloon: Primary 13.6×10^6 cu. ft. 3/4 mil. poly with cap: Contract AF19(628)-3291, Litten Industries
Backup: 4.8×10^6 cu. ft.
i. Telemetry: All project data to be telemetered, using range TM services.

Chan. 12	± 2.5V.
Chan. 13	0 - 5V.
Chan. 14	0 - 5V.
Chan. 15	0 - 5V.
Chan. 16	0 - 5V.

Transmitter frequency: 249.9 mc.

j. Command: Project requirements for 3 channels

Flight Equipment Description

a. Number of Project Packages in Load Train: Two (2)
b. Description of Packages:

(1) Load let-down reel - to deploy gondola to a distance of 500 ft.

(2) Main gondola - hexagonal shape, max. width: 71 inches

height of gondola: approx. 72 inches
overall height: aprox. 120 inches (because of "A" frame 48 inches above gondola to which project cabling is attached)

N.B. - Stud antenna (TM) attached beneath gondola

Provisions are made for accomodating AFCRL flight control and beacon packages on main gondola frame at opposite sides. General configuration will be very similar to the Hi-Altitude Co.'s Lunar Pointer.

(3) Total Weight of Project Payload - Main gondola - 325 lb.

Main gondola -	325 lb.
Let-down reel-	45 lb.
Total	370 lb.

(N.B. - does not include flight control equipment or parachute)

c. Distance between packages: N/A
d. Special Rigging Requirements:

(1) Nothing to be rigged beneath gondola which will electrically or mechanically obstruct TM antenna.
(2) Provision for load line separation after impact.
(3) Suspended load to be in static and dynamic equilibrium until flight termination.

e. Project checkout time prior to launch: 1 1/2 hr.
f. Dimensions of Scientific Package: 71 inch diam. by 140 inch height.
g. Critical Requirements Concerning Equipment during Launch:

It is very critical that launch procedures do not subject package to shock.

Project and Task Requirements:

a. Weather Requirements:

1. Meteorological conditions to assure smooth launch and flight profile to fulfill the purpose of each flight.

2. Visual observations of balloon function require that cloud cover will be a minimum in order to accomplish this.

b. Tracking: Optical, radar and a/c track to yield detailed position vs. time. After flight completion: horizontal and vertical profiles of flight path.

c. Photographic Coverage: Maximum coverage, by movies and stills, is required. The previous experience with these balloons has shown that detailed photo recording should be accomplished. A minimum of four different aspects of the balloon deployment and initial launch period is required.

d. Facilities Required: The usual facilities available at the AFCRL Balloon Test Site for previous flights are adequate.

e. Other:

1. It is requested that the Balloon Test Facility furnish:

(a) Parachutes, cutdown and safety equipment that is required.
(b) Liaison between project personnel and range TM personnel.

2. Recovery Information: Because of the high cost value of development and fabrication of the test equipment, it is essential that recovery be made as soon as possible after impact.

3. Data Services: Details of the data presentation by the Range-TM facility are reserved for discussion during the field operation period.

Project Participating Personnel

Name

1.	Robert B. Toolin AFCRL	AFCRL Project Field Director	617-274-6100 X2962
2.	Dr. Howard Edwards Georgia Inst. of Tech.	Principal Investigator Cont. AF19(628)-2416	404-873-4211 X267
3.	Mr. Z. Frentress Mr. E. Hodgdon Georgia Inst. of Tech.	Project Engineers - Test Equipment Cont AF19(628)-2416	Same
4.	Mr. A. Goddard Hi-Altitude Inst. Co.	Project Engineer - Solar Pointer contracting with Ga. Tech.	303-922-2712
5.	Mr. G. Nault Northeastern Univ.	Project Engineer - TM contracting with CRE	617-262-1100 X255

Project personnel concerned with this field test will arrive at AFMDC on or about 12 August 1964.

ROBERT B. TOOLIN
AFCRL Project Field Director
Optical Physics Laboratory

BALLOON FLIGHT 1407

PROJECT 7621 DESIMONE LAUNCH DATE 26 AUGUST 1964 LAUNCH SITE O3L HAFB NMEX CREW CHIEF MSG JOHNSON FTD CAPT JESSON CONTROL CENTER DIR MR MARKLEY MET MR GILDENBERG COORDINATOR TSGT MOSS ACFT SUPPORT U3A 886 ACFT OBS TSGT CARTER SSGT KERR MISSION FREQ 379.7 (MISSION DELTA GOLF).

0330 CONTROL CENTER OPENED TSGT MOSS ON DUTY.
0340 CREW DEPARTS FOR LAUNCH SITE.
0420 MR GILDENBERG ADVISES CLOCK TIME CHANGE TO 9 HOURS.
0430 MR GILDENBERG ADVISES CLOCK TIME CHANGE TO 10 HOURS MR RICHARDS ACKNOWLEDGES.
0435 INSTRUMENTATION CHECKOUT GOOD USING ZENITH 9730 WITH RADIOPHONE LEFT CONSOLE. CHECK ON 9026.5 ALSO GOOD ON ALL COMMANDS.
0445 PERMISSION GIVEN TO LAYOUT BALLOON.
0530 COMM CHECK WITH RANGE CONTROL
0532 INFLATION COMPUTATIONS RECEIVED AND CONFIRMED AT 220. BLEEDOWN
0620 FTD REQUESTS PERMISSION TO INFLATE AT 0630/H PIBAL AT 75 DEGREES/ PERMISSION GRANTED TO INFLATE AT 0630.
0620 SDP 4 (LAUNCH SITE ADVISES PACKAGE HOT AT 0617).
0625 MR RICHARDS ADVISES LAUNCH SITE WILL HAVE FINE BALLAST CONTROL, NOT TO TURN ON AT CONTROL/
0632 INFLATION STARTED
0636 BALLOON BURST WHILE INFLATING. WILL GET ANOTHER BALLOON AND LAUNCH
0640 RANGE CONTROL AND MISSION CONTROL ADVISED OF PROBLEMS REQUESTED 0800 LAUNCH/RANGE WILL CHECK AND CALL BACK.
0643 MSGT JOHNSON ADVISES OF WEIGHT CHANGES ACKNOWLEDGED BY MR GILDENBERG.
0650 TSC RADIO NOTIFIED OF APPROX 1 HR DELAY ON LAUNCH OF 1407. (DISREGARD 0650 NOTE)
0650 FTD WAS ADVISED NOT TO LAYOUT BALLOON UNTIL WORD IS RECEIVED FROM MISSION CONTROL ON OK TO GO.
0655 MISSION CONTROL ADVISES 0800 OR EARLIER OK U3A WILL SLIDE TO 0800 LAUNCH CREW CLEARED TO LAYOUT, INFLATE AND LAUNCH ASAP WHILE KEEPING CONTROL NOTIFIED OF PROGRESS. CREW CHIEF PASSES NEW INFLATION CONFIRMED BY (BDG)
0656 ADVISED TSC RADIO OF DELAY OF HIBAL 1407 (BLEEDDOWN OF 240 CONFIRMED 240 BDG.
0710 INSTR ADVISES OF HOT PACKAGE
0713 TORQUE VALUES ON GM 970 PLUS OR MINUS 25 LBS.
0715 INFLATION STARTED ON NR 2 BALLOON. MISSION CONTROL NOTIFIED OF ESTIMATED LAUNCH OF 0745.
0735 MISSION CONTROL AND TOWER NOTIFIED OF 5 MIN BEFORE LAUNCH
073338 FTD REQ PERMISSION TO LAUNCH IN 1 MIN/TOWER NOTIFIED AND APPROVED/ CLOCKS STARTED
0740/30 BALLOON LAUNCHED (ACTUAL 0741) TOWER NOTIFIED/
0744 REEL DOWN COMMAND ISSUED AND RECEIVED VISUAL AT LAUNCH SITE. (ISSUED BY MNB)

FLIGHT LOG 1407 26 AUG CONTINUED(

0747 ANTENNA DROP ISSUED AND RECEIVED/CODE READOUT LOUD AND CLEAR/(ISSUED BY MNB)

0805 UHF OUTPUT INOP RANGE ATTEMPTING TO CORRECT.

0820 CONTACT MADE WITH 886/

0835 886 LOST VISUAL ON BALLOON (CLOUDS).

0903 RECEIVED CALL FROM TSGT BLEVINS IN CASA GRANDE ARIZ INSTRUCTED TO CALL BACK AT 1000 MST.

0910 886 REQD TO RETURN TO HMN AND ALL PERSONNEL INCLUDING PILOT CALL CONTROL CNTR

0912 MISSION CONTROL NOTIFIED OF INTENT.

1030 BALLOON MAY BE ABORTED EARLY DUE TO CONTRACTOR TM FAILURE SSGT KERR FROM U3A AND A2C HOWELL WILL DEPART ASAP FOR RECOVERY. VICINITY ENGLE NMEX TSGT CARTER ONBORAD U3A APPROX 1115 TAKEOFF.

1051 2 MIN OF COMMAND BALLAST ISSUED BC ON 9026.5

1145 CUTDOWN INITIATED ON BALLOON/886 HAS NO VISUAL FPS 16 ON TRACK AGFT WAS ALERTED TO BE WATCHING FOR BALLOON AS WELL AS PARACHUTE FOR SAFETY/ CLOUD COVER TO GREAT FOR VISUAL TRACK.

1200 CONTR OFF COMMAND ISUED HGM(1155 ALL BALLAST DROPPED)HGM

1205 CONTR ON COMMAND ISSUED HGM

1206 CONTR OFF COMMAND ISSUED HGM

1205 866 HAS VISUAL ON PARACHUTE.

1200 BLEVINS FROM CASA GRANDE TO RETURN TO HMN.

1220 ALT 20K 866 STILL HAS VISUAL. ON PARACHUTE. CODE STILL 5x5 AT CONTROL

1235 7.5K RADAR LOST BALLOON.

1240-45 IMPACT OF PACKAGE ACFT ADVISES PARACHUTE DISENGAGED AND LANDED APPROX 2000 FT NE OF PACKAGE. ACFT WILL LEAD SDP 7 TO IMPACT AREA

1520 SD 7 AT IMPACT.

TELEMETERED PRESSURE ALTITUDE DATA
26 AUGUST 1964, FLIGHT #1407

Time MST	Kiloft MST	Time MST	Kiloft MST
0740	4.1	0917	65.0
0747	10.0	0926	70.0
0755.7	15.0	0934.5	75.0
0803.5	20.0	0945	80.0
0810	25.0	0957	85.0
0817	30.0	1006.5	90.0
0823	35.0	1017	95.0
0829	40.0	1028	100.0
0835	45.0	1042	105.0
0842.5	50.0	1100	110.0
0854	55.0	1115	119.0
0905	60.0	Radar Float, 122.7 Kiloft MSL (Geometric Height)	

30 April 1965

Detailed Balloon Flight Required

Project 7621 - Atmospheric Optics (770A) Task 762102

Laboratory - Optical Physics (CRO)

Branch - Atmospheric Optics (CROA)

Flight Title: Ultraviolet Sky Backgrounds

Flight Objective: To measure the spectral distribution of the intensity of natural sky radiation in the 2000 to 4000 Angstroms optical spectrum.

Security Classification: UNCLASSIFIED

Flight Information:

a. Desired Dates of Flight: June 14, 1965 period
b. Number of Flights: One (1)
c. Desired Launch Time: One-half to one hour before local sunrise
d. Duration and Altitude: Six-hour float at a maximum altitude, greater than 122,000 ft.
e. Minimum acceptable: One-hour float at 122,000 ft.
f. Ascent Rate requirement: 650 ft/min ± 100 ft/min.
g. Release: AFCRL operating site at AFMDC, New Mexico
h. Balloon: Primary to be determined upon recommendation of CRE personnel
   Backup: 0.75 mil Polyethylene: 4.85×10^6 cu. ft.
   Balloon #2 of 4 under Cont. AF19(628)-65-2519, Raven Ind.
i. Telemetry: All project data to be telemetered, using range TM services.

Chan. 2 -		(N.E.U.)	Battery volt for T.M.
Chan. 3 -		(N.E.U.)	Transmitter Case Temp.
Chan. 12 -	0-5V	(G.I.T.)	1/4 wave plate generator
Chan. 13 -	0-5V	(G.I.T.)	Commutated environmental and functioning data
Chan. 14 -	0-5V	(G.I.T.)	Commutated-grating pos. and guard cell operating
Chan. 15 -	0-5V	(G.I.T.)	MPT #1
Chan. 16 -	0-5V	(G.I.T.)	MPT #2

Transmitter frequency: 249.9 mc.

1. Command: Project requirements for 5 channels

   1. Activation of Let-Down Reel
   2. On-off command for solar biaxial pointer operation
   3. On-off command for TM transmitter

Flight Equipment Description

a. Number of Project Packages in Load Train: Two (2)
b. Description of Packages:

   (1) Load let-down reel - to deploy gondola to a distance of 500 ft.
       (1a) Visibility Pennant Deployment Unit
   (2) Main gondola - hexagonal shape, max. width; 71 inches
       height of gondola: approx. 72 inches
       overall height: approx. 120 inches (because of "A" frame 48 inches above gondola to which project cabling is attached)

       N.B. - Stud antenna (TM) attached beneath gondola

       Provisions are made for accomodating AFCRL flight control and beacon packages on main gondola frame at opposite sides. General configuration will be very similar to the 26 Aug. 1964 AFMDC flight.

   (3) Total Weight of Project Payload - Main gondola - 375 lb.
       Pennant unit and let-down reel

       (N.B. - does not include flight control equipment or parachute)

c. Distance between packages: N/A
d. Special Rigging Requirements:

   (1) Nothing to be rigged beneath gondola which will electrically or mechanically obstruct TM antenna.

   (2) The delicate optical instrumentation and potential damage would preclude the rigging of ballast hoppers above the main gondola. The previous rigging arrangement appeared to be satisfactory - except for the visibility flags. In this regard, it is proposed that the AFCRL (CRDA) flag deployment unit be used.

   (3) GIT will furnish impact signal for load line separation but will need squibs.

   (4) Suspended load to be in static and dynamic equilibrium until flight termination.

e. Project checkout time prior to launch: $1\frac{1}{2}$ hr.
f. Dimensions of Scientific Package: 71 in.diam. by 140 in.height.
g. Critical Requirements Concerning Equipment during Launch:

It is very critical that launch procedures do not subject package to shock.

Project and Task Requirements:

a. Weather Requirements:

1. Meteorological conditions to assure smooth launch and flight profile to fulfill the purpose of each flight.

2. Visual observations of balloon function require that cloud cover will be a minimum in order to accomplish this.

b. Tracking: Optical, radar and a/c track to yield detailed position vs. time. After flight completion: horizontal and vertical profiles of flight path.

c. Photographic Coverage: Maximum coverage, by movies and stills, is required. The previous experience with these balloons has shown that detailed photo recording should be accomplished. A minimum of four different aspects of the balloon deployment and initial launch period is required.

d. Facilities Required: The usual facilities available at the AFCRL Balloon Test Site for previous flights are adequate. Will also need the use of Environmental Chamber for test of main gondola.

e. Other:

1. It is requested that the Balloon Test Facility furnish:

(a) Parachutes, cutdown and safety equipment that is required
(b) Liaison between project personnel and range TM personnel

2. Recovery Information: Because of the high cost value of development and fabrication of the test equipment, it is essential that recovery be made as soon as possible after impact.

3. Data Services: Details of the data presentation by the Range-TM facility are reserved for discussion during the field operation period. Services will be similar to those furnished for the 26 August 1964 flight at AFMDC (Flt. #1407)

4. Services for Charging Batteries:

5 ea. BB405's
12 ea. LR 3

Project Participating Personnel

Name

1.	John D. Essex AFCRL	AFCRL Project Field Director	617-274-6100 X2964
2.	Dr. Howard Edwards Georgia Inst. of Tech.	Principal Investigator Cont. AF19(628)-2416	404-873-4211 X267
3.	Mr. Z. Frentress Mr. E. Hodgdon Mr. L. Willard Mr. T. Reed Georgia Inst. of Tech.	Project Engineers - Test Equipment Cont. AF19(628)-2416	Same
4.	Mr. A. Goddard Hi-Altitude Inst. Co.	Project Engineer - Solar Pointer Consulting with Ga. Tech.	 303-922-2712
5.	Mr. G. Nault Northeastern Univ.	Project Engineer - TM contracting with CRE	617-262-1100 X255

Project personnel concerned with this field test will arrive at AFMDC on or about 8-9 June 1965.

ROBERT B. TOOLIN
Chief, Atmospheric Optics Branch
Optical Physics Laboratory

BALLOON FLIGHT LOG

FLIGHT NR: H65-63 CHUTE: 64' O/W
PROJECT: 7621
DATE 1 JULY 1965, LAUNCH SITE RUNWAY 03 LEFT HAFB, LAUNCH TIME 0430, FLD DIR CAPT. JESSEN, LAUNCH CREW CHIEF MSGT JOHNSON, CONT CEN DIR MR MARKLEY, METEOR MR GILDENBERG, A2C SPERRY, COMM COOR MSGT BRAGG, COMD TECH MR ANDERSON, AIRCRAFT C-54 #557 T/O-0500, OBSERVES/RECOVERY TSGT MOSS SSGT NORRIS WITH VEHICLE SUPPORT FROM WILLIAMS AFB, ARIZ

0130 CONTROL CENTER OPEN//MSGT BRAGG ON DUTY//INFORMED THAT LAUNCH TIME IS NOW SCHEDULED FOR 0430 DUE TO WEATHER FORCAST
0115 COMD AND COMM EQUIP CHECKED 5X5
0135 LAUNCH CREW DEPARTED FOR LAUNCH SITE
0140 CONTROL CENTER CLOCKS SET WITH WWV
0146 CREW ARRIVED AT LAUNCH SITE
0205 COMMAND CHECK OUT STARTED AT THIS TIME//COULD NOT GET COMMAND CHECK OUT ON BACK UP CUT DOWN RECEIVER ON FIRST ATTEMPT//0225 COMMAND CHECK OUT COMPLETED ON ALL UNITS 5X5
NOTE: CHANGE OF WEIGHTS IN FLIGHT SYSTEM AS FOLLOWS; BALLOON-714 LBS, GROSS LOAD 1558 LBS, FREE LIFT-6%, FREE LIFT FACTOR-94 LBS, GROSS INFLATION -1652 LBS.
0254 BALLOON LAYOUT COMPLETED
0310 HELIUM COMPUTATION INFORMATION RECEIVED AT THIS TIME
0317 GAS VALVE OPEN COMMAND RECEIVED
0318 LETDOWN RECEIVER PACKAGE ON FREQ 6210 IS HOT//ALSO BACKUP CUT DOWN RECEIVER ON FREQ 9335 IS HOT//BALLOON BORNE TRANSMITTER ON FREQ 4902 RECEIVED AT THIS STATION
0325 THE TIME ON CLOCKS IS AS FOLLOWS; PRIMARY-605 MINS, SECONDARY-625 MINS, AND 20K MINIMUM ALTITUDE CLOCK SET FOR 155 MINS//CLOCKS STARTED AT 0411
0410 BLEED DOWN AS FOLLOWS; TRAILER NR 55L 3904 TO 200 PSI, TRAILER NR 52K 2524 TO 285 PSI.
0411 CONTRACTOR CHECK OUT COMPLETED//INFLATION STARTED 0416
0428 INFLATION COMPLETED FROM FIRST TRAILER//0438 INFLATION COMPLETED FROM SECOND TRAILER//CLEARED TO LAUNCH
0442 BALLOON LAUNCHED
0444 COMMAND ISSUED FOR GONDOLA REEL-DOWN//RECEIVED//ALTITUDE 5.6K
0509 20 SECS GAS VALVE ISSUED//RECEIVED
0525 25 SECS GAS VALVE ISSUED//RECEIVED
0655 AF#557 TOLD TO BREAK OFF OF THE MISSION AT 0700 AND PROCEED TO WILLIAMS AFB, ARIZ//REQUEST THAT THEY GIVE THIS STATION A CALL EVERY 15 MINS ON 8947KC//WE SILL REPLY ON 6910KC.
0915 RECEIVED A CALL VAI LAND LINE FROM TSGT MOSS AT WILLIAMS AFB//HE WAS INSTRUCTED TO DRIVE TO COOLIDGE, ARIZ AND SET UP A THEODOLITE AND GIVE THIS STATION A CALL WHEN HE MAKES CONTACT WITH THE BALLOON//EST CUT TIME TO BE 1230 LOCAL TIME

BALLOON FLIGHT LOG

FLIGHT NR. H65-63 CHUTE: 64' O/W
PROJECT: 7621
DATE 1 July 1965

0945 COMMAND ISSUED AND RECEIVED FOR POINTER-COMMAND-OFF//CONFIRMED BY JIG-1
0948 COMMAND ISSUED AND RECEIVED FOR POINTER-COMMAND-ON//CONFIRMED BY JIG-1
1000 A1C JOHNSON ON DUTY/SGT. BRAGG OFF DUTY.
1032 COMMAND 2ISSUED AND RECEIVED FOR POINTER-COMMAND-OFF
1035 COMMAND ISSUED AND RECEIVED FOR POINTER-COMMAND-~~OFF~~ ON
1037 COMMAND ISSUED AND RECEIVED FOR POINTER-COMMAND-OFF
1038 COMMAND ISSUED FOR TM OFF, NOT RECEIVED
103
1042 COMMAND ISSUED FOR TM OFF, NOT RECEIVED
1044 COMMAND ISSUED AND RECEIVED FOR POINTERCOMMAND ON
1110 RECOVERY CREW IS INSTRUCTED TO DEPART FOR ELOY, ARIZ. THE INSTRUCTIONS AT 0915 WERE CHANGED.
THE AIRCRAFT WILL TAKE OFF AT 1245
1120 RADAR WAS LOST AT 1015
1144 COMMAND ISSUED FOR TM OFF, 1 MIN., COMMAND NOT RECEIVED BY JIG-1
1215 TWO HR IMPACT NOTAM SENT TO T OR C RADIO
1257 COMMAND BALLAST FOR 2 MIN
1300 COMMAND BALLAST FOR 2 MIN
1303 COMMAND BALLAST FOR 2 MIN
1306 COMMAND BALLAST FOR 2 MIN
1309 COMMAND BALLAST FOR 1 MIN
1313 SGT. MOSS CALLED AT 1307 FROM ELOY AND WAS ADVISED TO GO TO COOLIGE ARIZ. ESTAMATED CUT TIME NOW IS 1350
1318 SGT. MOSS ADVISED TO STAY IN ELOY, ARIZ. CUT TIME 1350.MST
1337 COMMAND 1 ISSUED FOR POINTER COMMAND OFF
1339 COMMAND ISSUED FOR POINTER COMMAND ON
1341 COMMAND ISSUED FOR POINTER COMMAND OFF
1343 COMMAND ISSUED FOR POINTER COMMAND ON
1345 COMMAND ISSUED FOR POINTER COMMAND OFF, JIG 1CAN NOT CONFURME
1350 CUT DOWN COMMAND ISSUED FOR 30 SEC ON 7350KC
1352 COMMAND FOR CUT DOWN (BACKUP) WAS ISSUED FOR 1 MIN. ON 9335KC
1445 IMPACT IN COOLIDGE AREA VIA FFA, ADVISED TCS.
1500 STATION CLOSED..

Appendix B

Guidance and Control Directorate
DEPUTY FOR GUIDANCE TEST
Air Force Missile Development Center
Holloman Air Force Base, New Mexico
1 July 1965

TEST EVENT REPORT
Simulated Altitude Tests of Balloon Spectrometer
Project 6665

1. Title: Simulated Altitude Tests of the Georgia Institute of Technology Balloon Ultraviolet Spectrometer System, Project 6665, Balloon Components.

2. Background: The Georgia Institute of Technology Space Science Laboratory has designed and built an Ultraviolet Spectrometer balloon package which is to be flown at Holloman AFB approximately 25 June 1965. Mr. Brown, CREH, requested that the system be tested under Project 6665 in the Stratosphere Chamber prior to the actual balloon flight.

3. Discussion:

a. The purpose of the tests was to check the operation of the balloon spectrometer system under simulated pressure and temperature conditions experienced in actual balloon flight. Mr. Ellis Hodgdon, Graduate Research Assistant, Georgia Institute of Technology, was in charge of system operation and made all test arrangements. He was assisted in the system setup and operation by the following personnel: Mr. A. A. Goddard, Jr., Consultant, Hi Altitude Instrument Co., Inc., Mr. J. G. Nault, Research Assistant, Northeastern University, and Mr. J. J. Foust and Mr. T. P. Hollomon, Georgia Institute of Technology. All handling, operating, and monitoring of the spectrometer system was done by the above named personnel. Dr. Howard Edwards, Professor of Aerospace Engineering and Director of the Space Science Laboratory for Georgia Institute of Technology was also present for most of the testing.

b. The spectrometer system was subjected to three simulated altitude temperature tests in the Stratosphere Chamber, Building 1261. The simulated altitude and temperatures requested for the tests and the results obtained are shown in Figures 1, 2, and 3. Temperature readings were taken from 10 points on the spectrometer system for each test and recorded by the Data Logger along with readings of chamber conditions. Five copies of this data were given to Mr. Hodgdon. Copies of all recorded data were retained by MDSGL-2.

c. One hundred thirty two MDSGL-2 man-hours were required for the test series.

4. Summary: Georgia Tech. personnel encountered minor problems during the first test and requested the second test to pinpoint the problems. The second test indicated the problems were in the amplifier and mechanical brake. These were corrected and the system checked out good during the third test. Georgia Tech. personnel were satisfied with the test results.

ATWELL N. RUMSEY
Mechanical Engineer
Environmental Test Branch

Copies to:
MDS
MDSG
MDSGL
MDSGO
MDOPT
CREH/ Mr. Brown (3 cys)

```
COMMENT -- CALIBRATION PROGRAM                                          ;
BEGIN INTEGER M, SMP, U, SENS                                           ;
      REAL RNTIM1, RNTIM2, RNTIM3, PI, PI2                              ;
      FILE FIL2 6 (2,15)                                                ;
      FILE FILIN1 (2,10)                                                ;
      FILE IN FLDT1 "MULF2" "FTP1" (1,550)                              ;
      FILE FIL4 2 (1,10, SAVE 10)                                       ;
REAL PROCEDURE ARCCOS(X)      ;  VALUE X;  REAL X                       ;
BEGIN REAL T  ; IF ABS(X)=1.0 THEN T←1.57079633×SIGN(X) ELSE
                T ← ARCTAN(X/SQRT(1 - X*2))                             ;
                ARCCOS ← 1.57079633 - T END ARCCOS                      ;
REAL PROCEDURE ATAN(A,B) ; VALUE A,B ; REAL A,B                         ;
BEGIN REAL T; IF B=0 THEN T←1.57079633×SIGN(A) ELSE IF B<0 THEN
           T ← 3.14159266 +ARCTAN(A/B) ELSE T←ARCTAN(A/B)               ;
      IF T<0 THEN T←T+6.28318554                                        ;
      ATAN ← T END                                                      ;
FORMAT IN  FMTI1(3I4),
           FMTI2(4I6/7F10.6),
           FMTI3(6I2,X8,9L5),
           FMTI4(10I6)                                                  ;
FORMAT OUT FMT1("DATA PROCESSOR TIME: ", F8.2, " SECONDS"),
           FMT2("INPUT - OUTPUT TIME: ", F8.2, " SECONDS",              ;
           FMT3("TUBE LAM        CI          RR          RP       DELTA    ",
                "   ZETA      ETA")                                     ;
STREAM PROCEDURE WORD(A,B)                                              ;
BEGIN SI ← A; DI← B; SI ← SI - 8; DS ← 8 CHR     END                    ;
PROCEDURE DATE(FILEID)                                                  ;
      FILE FILEID                                                       ;
BEGIN ALPHA D; INTEGER I,DAY,YR ; LABEL L1; INTEGER ARRAY MO[1:12]      ;
      FORMAT OUT FMT("RUN DATE ", I2,"/",I2,"/",I2)                     ;
      FILL MO[*] WITH 31,28,31,30,31,30,31,31,30,31,30,31               ;
```

```
        D ←TIME(0)                                                          ;
        YR ← 10×D.[18:6] + D.[24:6]                                         ;
        DAY ← 100×D.[30:6] + 10×D.[36:6] + D.[42:6]                         ;
        IF DAY > (IF YR MOD 4 = 0 THEN 366 ELSE 365)    THEN
             GO TO L1                                                       ;
        I ←0                                                                ;
        FOR I ← I + 1 WHILE DAY > 0 DO                                 BEGIN
             DAY ←DAY - MO[I]                                               ;
             IF YR MOD 4 = 0 THEN IF I=2 THEN DAY ← DAY-1              END  ;
        I ← I-1                                                             ;
        DAY ←DAY + MO[I]                                                    ;
        WRITE (FILEID, FMT, I,DAY,YR)                                       ;
  L1:END DATE                                                               ;
  PROCEDURE DAYTIM(FILEID)                                                  ;
        FILE FILEID                                                         ;
  BEGIN INTEGER I1, I2, I3, T                                               ;
        FORMAT OUT FMT("RUN TIME ", I2,":",I2,":",I2)                       ;
        T ← TIME(1) DIV 60                                                  ;
        I1 ← T DIV 3600                                                     ;
        I2 ← (T - I1×3600) DIV 60                                           ;
        I3 ← T - I1×3600 - I2×60                                            ;
        WRITE (FILEID, FMT, I1, I2, I3)                                     ;
  END                                                                       ;
  PROCEDURE SORT(X,K)                                                       ;
        VALUE K                                                             ;
        INTEGER K                                                           ;
        ARRAY X[0]                                                          ;
  BEGIN INTEGER I,J,L                                                       ;
        ARRAY F[0:K-1]                                                      ;
        FOR J ← K-1 STEP -1 UNTIL 0 DO                                 BEGIN
             F[J] ←X[0]                                                     ;
             FOR I ← 1 STEP 1 UNTIL K-1 DO
                  IF X[I] > F[J] THEN                             BEGIN
                       F[J] ← X[I]                                          ;
                       L ← I                                      END       ;
             X[L] ← 0                                                  END  ;
```

```
      FOR I ← 0 STEP 1 UNTIL K-1 DO
           X[I] ← F[I]                                                    ;
END                                                                       ;
PROCEDURE COMPUTE(N,M,X,T,A,E,O,FILEID)                                   ;
      VALUE N,M,T,O                                                       ;
      FILE FILEID                                                         ;
      INTEGER N,M,O                                                       ;
      ARRAY X[0,0], A[0]                                                  ;
      INTEGER ARRAY E[0]                                                  ;
      REAL T                                                              ;
BEGIN INTEGER I,J,P, K,L                                                  ;
      REAL T1, T2, S, D                                                   ;
      BOOLEAN ZZ                                                          ;
      LABEL L1, L2                                                        ;
      ARRAY Z[0:M-1,0:M]                                                  ;
      ARRAY B,C[0:N-1]                                                    ;
      LIST LIST1(S, T1, T2, P),
      LIST2(FOR I ← 0 STEP 1 UNTIL P-1 DO [X[M,I],B[I],C[I]])             ;
      FORMAT OUT FMT1("STANDARD DEVIATION ",F10.5/X3,2(E12.5,X6),X2,I3),
                 FMT2(3(3(F10.5,X3)))                                     ;
      ZZ ← FALSE                                                          ;
      E[0] ←P ← N                                                         ;
      FOR I ← 1 STEP 1 UNTIL N DO
           E[I] ← I-1                                                     ;
L1:   T1 ← T2 ← 0                                                         ;
      FOR I ← 0 STEP 1 UNTIL M-1 DO
      FOR J ← 0 STEP 1 UNTIL M DO                                   BEGIN
           Z[I,J] ← 0                                                     ;
           FOR K ← 0 STEP 1 UNTIL P-1 DO
                Z[I,J] ← Z[I,J] + X[I,K]×X[J,K]                     END   ;
      FOR K ← M STEP -1 UNTIL 0 DO                                  BEGIN
           D ← 0                                                          ;
           FOR I ← 1 STEP 1 UNTIL K DO
                IF ABS(Z[I-1,0]) > D                   THEN  BEGIN
                     L ← I-1                                              ;
                     D ← ABS(Z[L,0])                         END          ;
```

```
    IF L>0                                              THEN
         FOR J ← 0 STEP 1 UNTIL K DO                          BEGIN
              D ← Z[L,J]                                                  ;
              Z[L,J] ← Z[0,J]                                             ;
              Z[0,J] ← D                                      END         ;
    FOR I ← 0 STEP 1 UNTIL M−1 DO
         A[I] ← Z[I,0]                                                    ;
    FOR J ← 1 STEP 1 UNTIL K DO                               BEGIN
         D ← Z[0,J]/A[0]                                                  ;
         FOR I ← 1 STEP 1 UNTIL M−1 DO
              Z[I−1,J−1] ← Z[I,J] − A[I]×D                                ;
         Z[M−1,J−1] ← D                                       END   END   ;
IF O = 1 THEN GO TO L2                                                    ;
FOR I ←0 STEP 1 UNTIL P−1 DO                                        BEGIN
    B[I] ← A[0]×X[0,I]                                                    ;
    FOR J ← 1 STEP 1 UNTIL M−1 DO
         B[I] ← B[I] + A[J]×X[J,I]                                        ;
    C[I] ← X[M,I] − B[I]                                                  ;
    T1 ← T1 + C[I]                                                        ;
    T2 ← T2 + C[I]*2                                                END   ;
T1 ← T1/P                                                                 ;
T2 ← T2/P                                                                 ;
S ← SQRT(T2 − T1*2)                                                       ;
IF O >3 THEN WRITE (FILEID, FMT2, LIST2)                                  ;
WRITE (FILEID, FMT1, LIST1)                                               ;
IF O = 3 OR O = 5 THEN                                              BEGIN
IF ZZ THEN GO TO L2                                                       ;
ZZ ← TRUE                                                                 ;
P ← 0                                                                     ;
FOR I ← 0 STEP 1 UNTIL N−1 DO
    IF ABS(C[I]) < T×S                                  THEN  BEGIN
         FOR J ← 0 STEP 1 UNTIL M DO
              X[J,P] ← X[J,I]                                             ;
         E[P+1] ← I                                                       ;
         P ← P + 1                                            END         ;
E[0] ← P                                                                  ;
```

```
        GO TO L1                                                          END  ;
L2:END COMPUTE                                                                 ;
REAL   PROCEDURE CALCPM(T,X)                                                   ;
       VALUE T,X ; REAL X; INTEGER T                                           ;
BEGIN  INTEGER J ; REAL S;                                                     ;
       ARRAY I[0:72], V[0:1,0:72]                                              ;
       FILL I[*] WITH 0,
       1.0@-4, 6.0@-4, 1.0@-3, 2.0@-3, 3.0@-3, 4.0@-3, 5.0@-3, 6.0@-3,
       7.0@-3, 8.0@-3, 9.0@-3, 1.0@-2, 1.1@-2, 1.2@-2, 1.3@-2, 1.4@-2,
       1.5@-2, 1.6@-2, 1.7@-2, 1.8@-2, 1.9@-2, 2.0@-2, 2.2@-2, 2.4@-2,
       2.6@-2, 2.8@-2, 3.0@-2, 3.5@-2, 4.0@-2, 4.5@-2, 5.0@-2, 5.5@-2,
       6.0@-2, 7.5@-2, 8.0@-2, 8.5@-2, 9.0@-2, 9.5@-2, 1.0@-1, 1.5@-1,
       2.0@-1, 2.5@-1, 3.0@-1, 3.5@-1, 4.0@-1, 4.5@-1, 5.0@-1, 5.5@-1,
       6.0@-1, 6.5@-1, 7.0@-1, 7.5@-1, 8.0@-1, 8.5@-1, 9.0@-1, 9.5@-1,
       1.0@-0, 1.1@-0, 1.2@-0, 1.3@-0, 1.4@-0, 1.5@-0, 1.6@-0, 1.7@-0,
       1.8@-0, 1.9@-0, 2.0@-0, 2.1@-0, 2.2@-0, 2.3@-0, 2.4@-0, 2.5@-0      ;
       FILL V[0,*] WITH 0.018,
       0.040,  0.169,  0.270,  0.501,  0.769,  1.003,  1.240,  1.520,
       1.710,  1.880,  2.010,  2.090,  2.130,  2.190,  2.225,  2.260,
       2.296,  2.330,  2.351,  2.380,  2.400,  2.430,  2.460,  2.498,
       2.520,  2.540,  2.560,  2.595,  2.630,  2.650,  2.690,  2.718,
       2.740,  2.795,  2.802,  2.820,  2.850,  2.865,  2.880,  3.030,
       3.100,  3.235,  3.280,  3.400,  3.465,  3.530,  3.570,  3.645,
       3.690,  3.751,  3.810,  3.870,  3.930,  3.985,  4.040,  4.095,
       4.150,  4.245,  4.350,  4.450,  4.550,  4.660,  4.750,  4.852,
       4.951,  5.051,  5.179,  5.250,  5.340,  5.430,  5.470,  5.510       ;
       FILL V[1,*] WITH 0.019,
       0.038,  0.040,  0.245,  0.488,  0.750,  0.990,  1.210,  1.430,
       1.630,  1.750,  1.860,  1.940,  1.995,  2.040,  2.070,  2.100,
       2.128,  2.155,  2.180,  2.208,  2.230,  2.250,  2.296,  2.330,
       2.360,  2.385,  2.400,  2.448,  2.480,  2.503,  2.540,  2.570,
       2.595,  2.675,  2.690,  2.715,  2.738,  2.750,  2.765,  2.885,
       2.980,  2.080,  3.165,  3.235,  3.288,  3.345,  3.370,  3.400,
       3.500,  3.555,  3.610,  3.670,  3.720,  3.777,  3.845,  3.895,
       3.920,  4.032,  4.128,  4.223,  4.318,  4.420,  4.500,  4.600,
       4.695,  4.785,  4.880,  4.970,  5.058,  5.155,  5.249,  5.350       ;
```

```
        IF T = 0 THEN S1←-0.7796+0.003196×X ELSE S1←-0.9028+0.003254×X     ;
        IF S1<V[T,0] THEN S1←V[T,0] ELSE IF S1>V[T,72] THEN S1←V[T,72]     ;
        J ← 0                                                              ;
        DO J←J+9 UNTIL S1 ≤ V[T,J]                                         ;
        DO J←J-1 UNTIL S1 ≥ V[T,J]                                         ;
        CALCPM←I[J]+(I[J+1]-I[J])×(S1-V[T,J])/(V[T,J+1]-V[T,J])      END   ;
        PI ← 3.14159265                                                    ;
        PI2 ← PI/2                                                         ;
        SENS ← 0                                                           ;
        DATE (FIL2)                                                        ;
        DAYTIM(FIL2)                                                       ;
        WRITE (FIL2[DBL])                                                  ;
        READ (FILIN1, FMTI1, M, SMP, U)                                    ;
BEGIN   INTEGER Q,M1,L,STRTTM,LEVEL,LAMBDA1, LAMBDA2                       ;
        REAL BKTIM, BRKTIM, OMGA, PSID                                     ;
        ARRAY PSI[0:M-1], ETAAR,ZETAAR[0:1]                                ;
        INTEGER ARRAY N[0:M-1], OPT[0:5], LAMBDA[0:U-1]                    ;
        FILE FTAPE1 2 (1,3×SMP+4,SMP, SAVE 10)                             ;
        BOOLEAN ARRAY Z[0:10]                                              ;
        ALPHA TUBE                                                         ;
        LABEL L1                                                           ;
        LIST LISTI1(STRTTM,LEVEL,LAMBDA1,LAMBDA2,BRKTIM,OMGA,PSID,
             ETAAR[0],ETAAR[1], ZETAAR[0], ZETAAR[1]),
             LISTI2(FOR L←0 STEP 1 UNTIL 5 DO OPT[L],FOR L←0 STEP 1
                    UNTIL 8 DO Z[L]),
             LISTI3(FOR L ← 0 STEP 1 UNTIL U-1 DO LAMBDA[L])               ;
        READ (FILIN1, FMTI2, LISTI1)                                       ;
        READ (FILIN1, FMTI3, LISTI2)                                       ;
        READ (FILIN1, FMTI4, LISTI3)                                       ;
        CLOSE (FILIN1, RELEASE)                                            ;
        FOR L ← 0 STEP 1 UNTIL M-1 DO                                BEGIN
             N[L] ←SMP                                                     ;
             PSI[L] ← L×PSID×0.0174532925                            END   ;
        SORT (LAMBDA,U)                                                    ;
        WORD(FLDT1(0),M1)                                                  ;
BEGIN   INTEGER I,J,K,P,R                                                  ;
```

```
        REAL S, OMEGA, OMIN, OMAX, A1, B1                                        ;
        ALPHA ARRAY A[0:M1+5]                                                   ;
        BOOLEAN Z1                                                              ;
        ARRAY G[0:M1/4], GEN[0:SMP-1], H[0:1,0:SMP-1], TIM[0:M-1],C[0:21];
        INTEGER ARRAY BLOCK[0:M-1]                                              ;
        LABEL L1, L2, L3, L4, L5, L6, L7, LE1, LE2, LE3,LP1, LP2, LP3          ;
LIST    LIST1 (K, A1, B1, C[K], OMEGA),
        LIST2(FOR I ← 0 STEP 1 UNTIL N[R]-1 DO GEN[I]),
        LIST3(FOR I ← 0 STEP 1 UNTIL N[R]-1 DO H[0,I]),
        LIST4(FOR I ← 0 STEP 1 UNTIL N[R]-1 DO H[1,I]),
        LIST5(FOR I ← 0 STEP 1 UNTIL M-1 DO [BLOCK[I],TIM[I]])                 ;
FORMAT OUT FMT1(/"REFERENCE GENERATOR FREQUENCY APPROXIMATION"),
             FMT2(10(F7.1,X4)),
             FMT3(/"ARRAY GEN[*] - GENERATOR OUTPUT"),
             FMT4(/"ARRAY H[0,*] - 30 KC PM TUBE"),
             FMT5(/"ARRAY H[1,*] - 40 KC PM TUBE"),
             FMT6(/"CALIBRATION TIMES AND BLOCK NUMBERS"),
             FMT7(5(I5,X2,F10.3,X4)),
             FMT8(I2, X2, 3(E15.8,X4),X3, F10.6),
             FMT9(/"START TIME TOO LARGE"),
             FMT10(/"END OF FILE -- R= ", I3),
             FMT11(/"END OF FILE - STAGE 2 -- R= ", I3),
             FMT12(/"PROGRAM ERROR - END OF FILE CALIBRATION TAPE"),
             FMT13(/"PARITY ERROR BEFORE STARTING TIME -- BLOCK: ", I4),
             FMT14(/"PARITY ERROR STAGE 1 - BLOCK: ",I4,X3,"R= ",I3),
             FMT15(/"PARITY ERROR STAGE 2 - BLOCK: ",I4,X3,"R= ",I3),
             FMT16(////"# ",I2," RELATIVE ANGLE OF INCIDENT POLARIZATION",
                   " -- ", F8.3, " RADIANS"),
             FMT17(//"NUMBER OF SAMPLES PER ANGLE OF INCIDENT",
                   " POLARIZATION: ",I4/"NUMBER OF ANGLES OF INCIDENT",
                   " POLARIZATION: ", I3)                                       ;
        L ← 0                                                                   ;
        R ← -1                                                                  ;
        P ← (M1-3) DIV 4 - 1                                                    ;
L1:     READ (FLDT1,2,A[*])[LE1:LP1]                                           ;
        IF A[1].[30:17] < STRTTM                              THEN
```

```
          GO TO L1                                                        ;
      SPACE (FLDT1,-1)[L5]                                                ;
L2:   READ (FLDT1[NO], 1, A[*])[LE2:LP2]                                  ;
      WORD (FLDT1(O), M1)                                                 ;
      READ (FLDT1, M1, A[*])                                              ;
      IF Z1 AND A[M1-1].[1:13] < LAMBDA[L]                THEN
          GO TO L2                                                        ;
      FOR J ← 3 STEP 4 UNTIL M1-1 DO                                   BEGIN
          IF A[J+1].[14:11] > LEVEL                       THEN
              IF NOT Z1                                   THEN  BEGIN
                  R ← R+1                                                 ;
                  Z1 ← TRUE                                     END       ;
          IF Z1                                           THEN
          IF A[J].[1:13] = LAMBDA[L]                      THEN  BEGIN
              TIM[R] ← A[1].[30:17] + A[J].[25:8] - A[3].[25:8]
                      + A[J].[33:10]/1000                                 ;
              BLOCK[R] ← A[0]                                             ;
              IF R=0 AND L=0                              THEN
                  FOR I ←0 STEP 1 UNTIL P DO
                      G[I] ← A[4×I+3].[14:11]                             ;
              K ← J-2                                                     ;
              FOR I ← 0 STEP 1 UNTIL N[R]-1 DO                  BEGIN
                  IF 4×I+K > M1-2                         THEN  BEGIN
                      READ (FLDT1, M1, A[*])[LE3:LP3]                     ;
                      SPACE(FLDT1,-1)                                     ;
                      K ← 5 - 4×I                               END       ;
L3:               IF A[4×I+K].[43:5] ≠ 3                  THEN  BEGIN
                      K ← K + 1                                           ;
                      GO TO L3                                  END       ;
                  GEN[I] ← A[4×I+K-2].[14:11]                             ;
                  H[0,I] ← A[4×I+K].[14:11]                               ;
                  H[1,I] ← A[4×I+K+1].[14:11]                             ;
                                                                END       ;
      IF Z[0]                                             THEN  BEGIN
          WRITE (FIL2, FMT16, R, PSI[R])                                  ;
          WRITE (FIL2, FMT3)                                              ;
```

```
           WRITE (FIL2, FMT2, LIST2)                                     ;
           WRITE (FIL2, FMT4)                                            ;
           WRITE (FIL2, FMT2, LIST3)                                     ;
           WRITE (FIL2, FMT5)                                            ;
           WRITE (FIL2, FMT2, LIST4)                          END        ;
                WRITE (FTAPE1, N[R], GEN[*])                             ;
                WRITE (FTAPE1, N[R], H[0,*])                             ;
                WRITE (FTAPE1, N[R], H[1,*])                             ;
                SPACE (FLDT1,-1)                                         ;
                L ← L +1                                                 ;
                IF L < U                                THEN
                     GO TO L2                           ELSE  BEGIN
                     Z1 ← FALSE                                          ;
                     IF R < M-1                         THEN  BEGIN
                          L ← 0                                          ;
                          GO TO L2                            END
                                                        ELSE
                          GO TO L4                            END        ;
                                                              END   END  ;
      GO TO L2                                                           ;
LE1:  WRITE (FIL2, FMT9)                                                 ;
      SENS ← 1                                                           ;
      GO TO L4                                                           ;
LE2: WRITE (FIL2, FMT10, R)                                              ;
      IF R > 6                                          THEN
           M ← R + 1                                    ELSE
           SENS ← 1                                                      ;
      GO TO L4                                                           ;
LE3: WRITE (FIL2, FMT11, R)                                              ;
      IF R > 7                                          THEN
           M ← R                                        ELSE
           SENS ← 1                                                      ;
      GO TO L4                                                           ;
L5:   WRITE (FIL2, FMT12)                                                ;
      SENS ← 1                                                           ;
      GO TO L4                                                           ;
```

```
LP1:  RELEASE (FLDT1)                                                  ;
      WRITE (FIL2, FMT13, A[0])                                        ;
      GO TO L1                                                         ;
LP2:  RELEASE (FLDT1)                                                  ;
      WRITE (FIL2, FMT14, A[0], R)                                     ;
      Z1 ← FALSE                                                       ;
      FOR I ← R STEP 1 UNTIL M-2 DO
           PSI[I] ← PSI[I+1]                                           ;
      M ← M-1                                                          ;
      IF M > 8                                       THEN  BEGIN
           SENS ← 1                                                    ;
           GO TO L4                                        END         ;
      IF R < M                                       THEN
           GO TO L2                                  ELSE
           GO TO L4                                                    ;
LP3:  RELEASE (FLDT1)                                                  ;
      WRITE (FIL2, FMT15, A[0], R)                                     ;
      Z1 ← FALSE                                                       ;
      FOR I ← R STEP 1 UNTIL M-2 DO
           PSI[I] ← PSI[I+1]                                           ;
      M ← M-1                                                          ;
      IF M > 8                                       THEN  BEGIN
           SENS ← 1                                                    ;
           GO TO L4                                        END         ;
      IF R < M                                       THEN
           GO TO L2                                  ELSE
           GO TO L4                                                    ;
L4:   REWIND (FTAPE1)                                                  ;
      IF Z[1]                                        THEN        BEGIN
           WRITE (FIL2, FMT17, SMP, M)                                 ;
           WRITE (FIL2, FMT6)                                          ;
           WRITE (FIL2, FMT7, LIST5)                             END   ;
      LOCK (FLDT1, RELEASE)                                            ;
      OMIN ← 0.9×OMGA                                                  ;
      OMAX ← 1.1×OMGA                                                  ;
      S ← (OMAX-OMIN)/10.0                                             ;
```

```
        IF Z[2]                                                 THEN
            WRITE (FIL2, FMT1)                                                   ;
L6:     K ← 0                                                                    ;
        FOR OMEGA ← OMIN STEP S UNTIL OMAX DO                              BEGIN
            A1 ← B1 ← 0                                                          ;
            FOR I ← 0 STEP 1 UNTIL P DO                               BEGIN
                A1 ← A1 + G[I]×COS(I×OMEGA)                                      ;
                B1 ← B1 + G[I]×SIN(I×OMEGA)                           END        ;
            C[K] ← A1*2 + B1*2                                                   ;
        IF Z[2]                                                 THEN
            WRITE(FIL2, FMT8, LIST1)                                             ;
            K ← K + 1                                                      END   ;
            A1 ← C[0]                                                            ;
            FOR I ← 1 STEP 1 UNTIL K-1 DO
                IF C[I] > A1                                    THEN       BEGIN
                    A1 ← C[I]                                                    ;
                    OMGA ← OMIN + I×S                                      END   ;
        IF (OMAX-OMIN)/OMGA < 0.01                              THEN
            GO TO L7                                                             ;
        OMIN ← OMGA - S                                                          ;
        OMAX ← OMGA + S                                                          ;
        S ← S/10.0                                                               ;
        GO TO L6                                                                 ;
L7:END *                                                                         ;
        IF SENS = 1                                             THEN
            GO TO L1                                                             ;
        FOR L ← 0 STEP 1 UNTIL U-1 DO
BEGIN   INTEGER I,J,Q, K                                                         ;
        ARRAY GEN[0:SMP-1],PM[0:1,0:M-1,0:SMP-1], A[0:7],
             X[0:7,0:IF M>SMP THEN M-1 ELSE SMP-1],THETA2[0:M-1,0:SMP-1];
        REAL PHI, AMP, R, OMEGA                                                  ;
        INTEGER ARRAY B[0:SMP]                                                   ;
        LIST LIST1(FOR I ← 0 STEP 1 UNTIL N[J]-1 DO THETA2[J,I])                 ;
FORMAT OUT FMT1(/"REFERENCE GENERATOR DATA -- SMALL ANGLE APPROXIMATION"
                 ),
            FMT2(9(F10.5,X2)),
```

```
     FMT3(/"REFERENCE GENERATOR CURVEFITTING DATA"),
     FMT4(3(F12.6,X4)/X2,3(F12.6,X2))                                    ;
SPACE (FTAPE1, 3×L)                                                      ;
FOR J ← 0 STEP 1 UNTIL M-1 DO                                       BEGIN
     READ (FTAPE1, N[J], GEN[*])                                         ;
     READ (FTAPE1, N[J], PM[0,J,*])                                      ;
     READ (FTAPE1, N[J], PM[1,J,*])                                      ;
     IF J ≠ M-1                                   THEN
          SPACE(FTAPE1, 3×(U-1))                                         ;
FOR I ← 0 STEP 1 UNTIL SMP-1 DO                                     BEGIN
     X[0,I] ← 1.0                                                        ;
     X[1,I] ← SIN(I×OMGA)                                                ;
     X[2,I] ← COS(I×OMGA)                                                ;
     FOR K ← 1,2 DO                                          BEGIN
          X[2×K+1,I] ← X[1,I]×(I*K)                                      ;
          X[2×K+2,I] ← X[2,I]×(I*K)                          END         ;
     X[7,I] ← GEN[I]                                                END  ;
COMPUTE (N[J],7,X,1,2,A,B,OPT[0],FIL2)                                   ;
PHI ← ATAN(A[2],A[1])                                                    ;
IF ABS(A[4]-A[3]) > 0.001                         THEN
     IF ABS(A[2]) > ABS(A[1])                     THEN
          OMGA ← OMGA - A[3]/A[2]                 ELSE
          OMGA ← OMGA + A[4]/A[1]                                        ;
IF Z[3]                                           THEN              BEGIN
     WRITE (FIL2, FMT1)                                                  ;
     WRITE (FIL2, FMT2, PHI,OMGA,FOR I←0,1,2,3,4,5,6 DO A[I])END         ;
FOR I ← 0 STEP 1 UNTIL B[0]-1 DO                                    BEGIN
     X[1,I] ← SIN(OMGA×B[I+1])                                           ;
     X[2,I] ← COS(OMGA×B[I+1])                                           ;
     X[3,I] ← GEN[B[I+1]]                                           END  ;
COMPUTE (B[0],3,X,1,2,A,B,OPT[1],FIL2)                                   ;
PHI ← ATAN(A[2],A[1])                                                    ;
AMP ← SQRT(A[1]*2+A[2]*2)                                                ;
IF Z[4]                                           THEN              BEGIN
     WRITE (FIL2, FMT3)                                                  ;
     WRITE (FIL2, FMT4,A[0],AMP,PHI,FOR I←0,1,2 DO A[I])            END  ;
```

```
FOR I ← 0 STEP 1 UNTIL N[J]-1 DO                                   BEGIN
     R ← (GEN[I]-A[0])/AMP                                              ;
     OMEGA ← PHI + I×OMGA                                               ;
     IF I > 1                                            THEN
          OMEGA ← (2×THETA2[J,I-1]-THETA2[J,I-2]+OMEGA)/2               ;
     IF ABS(R) ≤ 1.0                                     THEN  BEGIN
          R ← PI/2 - ARCCOS(R)                                          ;
          K ←ENTIER(OMEGA/PI2)                                          ;
          IF K ≤ 0                                       THEN
          THETA2[J,I] ← R                                ELSE  BEGIN
               K ← K+1                                                  ;
               IF K MOD 4 ≤ 1                            THEN
                    THETA2[J,I] ← PI×(K DIV 2) + R
                                                         ELSE
                    THETA2[J,I] ← PI×(K DIV 2) - R
                                                               END
                                                               END
                                                         ELSE
          THETA2[J,I] ← OMEGA                                     END   ;
     IF Z[4]                                             THEN
          WRITE (FIL2, FMT2, LIST1)                                     ;
                                                                  END   ;
REWIND (FTAPE1)                                                         ;
IF L = U-1                                               THEN     BEGIN
     BREAK                                                              ;
     BKTIM ← TIME(2)                                                    ;
     CLOSE (FTAPE1, PURGE)                                        END   ;
FOR Q ← 0 STEP 1 UNTIL 1 DO                                       BEGIN
IF TIME(2) - BKTIM > 3600×BRKTIM                         THEN     BEGIN
     BREAK                                                              ;
     BKTIM ← TIME(2)                                              END   ;
IF LAMBDA[L] > LAMBDA2                                   THEN
     Q ← 1                                                              ;
IF Q = 0                                                 THEN
     TUBE ← "541F"                                       ELSE
     TUBE ← "541A"                                                      ;
```

```
      FOR J ← 0 STEP 1 UNTIL M-1 DO
           FOR I ← 0 STEP 1 UNTIL N[J]-1 DO
                PM[Q,J,I] ← CALCPM(Q,PM[Q,J,I])                                  ;
BEGIN INTEGER I,J,K                                                               ;
      LABEL L1,L2                                                                 ;
      REAL PSI2, ETA, XI21, XI22, ZETA, BETA2, RR2, RR, RP2, RP,
           COSDLT, DELTA, K1, CI, POL, V                                          ;
      ARRAY A1,B[0:M-1,0:4],D[0:9], C[0:4,0:2],X1[0:1,0:M-1],A[0:4]             ;
      INTEGER ARRAY U1,U3[0:SMP], U2,U4[0:4,0:M]                                  ;
LIST  LIST1(FOR J ← 0 STEP 1 UNTIL M-1 DO FOR K← 0,1,2,3,4 DO B[J,K]),
      LIST2(FOR I ← 0,1,2 DO FOR K ← 0,1,2,3,4 DO C[K,I]),
      LIST3(ETA, XI21, XI22, ZETA),
      LIST4(FOR J ← 0 STEP 1 UNTIL M-1 DO FOR K ← 0,1,2,3,4 DO A1[J,K]),
      LIST5(FOR I ← 0 STEP 1 UNTIL 9 DO D[I]),
      LIST6(FOR I←0 STEP 1 UNTIL 9 DO [I,D[I]], RR2, RP2),
      LIST7(FOR I←0 STEP 1 UNTIL 9 DO [I,D[I]], RR, COSDLT, RP2),
      LIST8(FOR I←0 STEP 1 UNTIL 9 DO [I,D[I]], RR, DELTA, RP2),
      LIST9 (LAMBDA[L], CI, RR, RP, DELTA, ZETA, ETA),
      LIST10(Q,LAMBDA[L], CI, RR, RP, DELTA, ZETA, ETA),
      LIST11(POL,V,PHI)                                                           ;
FORMAT OUT FMT1(/"ARRAY B"),
           FMT2(5(E12.5, X4)),
           FMT3(/"ARRAY C"),
           FMT4("ETA ", F9.6,X4,"XI2 ", 2(F8.6,X3)/"ZETA",F9.6/),
           FMT5(/"ARRAY A"),
           FMT6(/"ARRAY D"),
                 FMT7(/"COMPUTE ERROR = ARRAY D"/5(I2,X1,E12.5,X3)/
                       4(I2,X1,E12.5,X3)/I2,X1,E12.5,X3),
                 FMT8(/"COMPUTE ERROR = ARRAY D"/2(5(I2,X1,E12.5,X3)/),
                       "RR2= ", E12.5/"RP2= ", E12.5),
                 FMT9(/"COMPUTE ERROR = ARRAY D"/2(5(I2,X1,E12.5,X3)/),
                       "RR= ",F10.5/"COS(DELTA)= ",E12.5/"RP2= ",E12.5),
                 FMT10(/"COMPUTE ERROR = ARRAY D"/2(5(I2,X1,E12.5,X3)/),
                       "RR= ",F10.5/"DELTA= ",F10.6/"RP2= ", E12.5),
           FMT11(X4,A4),
           FMT12("LAMBDA: ", I5/"CI ",E13.6,X3,"RR ",F10.8,X3,"RP ",
```

```
            F10.8,X3,"DELTA ", F12.8/X19,"ZETA ",F10.7,X1,"ETA ",
            F10.7),
       FMT13(I2,X2,I4,X2,E13.6, 5(F10.7,X1)),
       FMT14(X63, "P ", F6.3, X4,"V ",F6.3," PHI",F7.3)                       ;
FOR I ← 0 STEP 1 UNTIL IF SMP>M THEN SMP-1 ELSE M-1 DO
       X[0,I] ← 1.0                                                            ;
IF Z[7+Q]                                          THEN         BEGIN
       ETA ← ETAAR[Q]                                                          ;
       ZETA ←ZETAAR[Q]                                                         ;
       U1[0] ← SMP                                                             ;
       FOR I ← 0 STEP 1 UNTIL SMP-1 DO
            U1[I+1] ← I                                                        ;
       FOR I ← 0,1,2,3,4 DO                                     BEGIN
            U2[I,0] ← M                                                        ;
            FOR J ←0 STEP 1 UNTIL M-1 DO
                 U2[I,J+1] ← J                                  END            ;
       GO TO L1                                                         END    ;
FOR J ← 0 STEP 1 UNTIL M-1 DO                                           BEGIN
       FOR I ← 0 STEP 1 UNTIL N[J]-1 DO                         BEGIN
            X[1,I] ← SIN(THETA2[J,I])                                          ;
            X[2,I] ← COS(THETA2[J,I])                                          ;
            X[3,I] ← SIN(2×THETA2[J,I])                                        ;
            X[4,I] ← COS(2×THETA2[J,I])                                        ;
            X[5,I] ← PM[Q,J,I]                                  END            ;
       COMPUTE (N[J],5,X,0.9,B[J,*], U1,OPT[2],FIL2)                    END    ;
WRITE (FIL2, FMT1)                                                             ;
WRITE (FIL2, FMT2, LIST1)                                                      ;
FOR J ← 0 STEP 1 UNTIL M-1 DO                                           BEGIN
       PSI2 ← 2×PSI[J]                                                         ;
       X[1,J] ← X1[0,J] ← SIN(PSI2)                                            ;
       X[2,J] ← X1[1,J] ← COS(PSI2)                                     END    ;
FOR I ← 0,1,2 DO                                                        BEGIN
       FOR J ← 0 STEP 1 UNTIL M-1 DO
            X[3,J] ← B[J,I]                                                    ;
       COMPUTE (M,3,X,0.9,C[I,*],U2[I,*],OPT[3],FIL2)                   END    ;
FOR I ← 3,4 DO                                                          BEGIN
```

```
        FOR J ← 0 STEP 1 UNTIL M-1 DO                            BEGIN
            X[0,J] ← X1[0,J]                                                 ;
            X[1,J] ← X1[1,J]                                                 ;
            X[2,J] ← B[J,I]                                      END         ;
        COMPUTE (M,2,X,0.9,C[I,*],U2[I,*],OPT[3],FIL2)                 END   ;
    WRITE (FIL2, FMT3)                                                       ;
    WRITE (FIL2, FMT2, LIST2)                                                ;
    ETA ← 0.5×ATAN(-C[0,1],C[0,2])                                           ;
    XI21 ← 0.5×ATAN(C[3,1],C[3,0])                                           ;
    XI22 ← 0.5×ATAN(-C[4,0],C[4,1])                                          ;
    IF ABS(XI21-XI22) < 0.26                                 THEN
        ZETA ← (ETA - (XI21+XI22)/2)/2                       ELSE
        IF ABS(C[3,1]) > ABS(C[4,2])                         THEN
            ZETA ← (ETA - XI21)/2                            ELSE
            ZETA ← (ETA - XI22)/2                                            ;
    WRITE (FIL2, FMT4, LIST3)                                                ;
    FOR I ← 0 STEP 1 UNTIL IF SMP>M THEN SMP-1 ELSE M-1 DO
        X[0,I] ← 1.0                                                         ;
L1: FOR J ← 0 STEP 1 UNTIL M-1 DO                                     BEGIN
        FOR I ← 0 STEP 1 UNTIL U1[0]-1 DO                        BEGIN
            BETA2 ← ZETA×2 + THETA2[J,U1[I+1]]                               ;
            X[1,I] ← SIN(BETA2)                                              ;
            X[2,I] ← COS(BETA2)                                              ;
            X[3,I] ← SIN(2×BETA2)                                            ;
            X[4,I] ←COS(2×BETA2)                                             ;
            X[5,I] ← PM[Q,J,U1[I+1]]                             END         ;
        COMPUTE(U1[0],5,X,0.9,A1[J,*],U3,OPT[4], FIL2)                 END   ;
    WRITE (FIL2, FMT5)                                                       ;
    WRITE (FIL2, FMT2, LIST4)                                                ;
    FOR I ← 0 STEP 1 UNTIL M-1 DO                                     BEGIN
        X1[0,I] ← SIN(2×(PSI[I] + ETA))                                      ;
        X1[1,I] ← COS(2×(PSI[I] + ETA))                                END   ;
    FOR I ← 0,1,2 DO                                                  BEGIN
        FOR J ←0 STEP 1 UNTIL U2[I,0]-1 DO                       BEGIN
            X[1,J] ← X1[IF I=1 THEN 0 ELSE 1,U2[I,J+1]]                      ;
            X[2,J] ← A1[U2[I,J+1],I]                             END         ;
```

```
          COMPUTE (U2[I,0],2,X,0.9,A,U4[I,*],OPT[5],FIL2)                   ;
          FOR J ← 0,1 DO
               D[2×I+J] ← A[J]                                         END  ;
     FOR I ← 3,4 DO                                                    BEGIN
          FOR J ← 0 STEP 1 UNTIL U2[I,0]-1 DO                    BEGIN
               X[0,J] ← X1[IF I=4 THEN 1 ELSE 0,U2[I,J+1]]                  ;
               X[1,J] ← A1[U2[I,J+1],I]                          END        ;
          COMPUTE (U2[I,0],1,X,0.9,A,U4[I,*],OPT[5],FIL2)                   ;
          D[2×I] ←A[0]                                                 END  ;
     WRITE (FIL2, FMT6)                                                     ;
     WRITE (FIL2, FMT2, LIST5)                                              ;
     FOR I ←0 STEP 1 UNTIL 9 DO
          D[I] ← ABS(D[I])                                                  ;
     D[3] ← (D[3] + D[5])/2                                                 ;
     D[5] ← (D[6] + D[8])/2                                                 ;
     D[6] ← (D[0] - D[4])/(D[0] + D[4])                                     ;
     D[7] ← (D[1] + D[5] - D[3])/(D[1] + D[5] + D[3])                       ;
     D[8] ← D[6]×D[7]                                                       ;
     D[9] ← (1 - D[6]*2)×(1 - D[7]*2)                                       ;
     IF D[9] ≥ 0                                            THEN
          D[9] ← SQRT(D[9])                                 ELSE       BEGIN
          WRITE (FIL2, FMT7,LIST5)                                          ;
          GO TO L2                                                     END  ;
     WRITE (FIL2, FMT6)                                                     ;
     WRITE (FIL2, FMT2, LIST5)                                              ;
     RP2 ← (1 - D[8] - D[9])/(D[6] - D[7])                                  ;
     RR2 ← (1 + D[8] - D[9])/(D[6] + D[7])                                  ;
     IF RR2 ≥ 0                                             THEN
          RR ← SQRT(RR2)                                    ELSE       BEGIN
          WRITE (FIL2, FMT8, LIST6)                                         ;
          GO TO L2                                                     END  ;
     COSDLT ← ((D[1]-D[5])/(D[1]+D[5]))×(1+RR2)/(2×RR)                      ;
     IF ABS(COSDLT) ≤ 1.0                                   THEN
          DELTA ← ARCCOS(COSDLT)                            ELSE       BEGIN
          WRITE (FIL2, FMT9, LIST7)                                         ;
          GO TO L2                                                     END  ;
```

```
        IF RP2 ≥ 0                                                  THEN
            RP ← SQRT(RP2)                                          ELSE         BEGIN
            WRITE (FIL2, FMT10, LIST8)                                              ;
            GO TO L2                                                             END  ;
        CI ← D[0]/((1 + RR2)×(1 + RP2))                                             ;
        WRITE (FIL2, FMT11, TUBE)                                                   ;
        WRITE (FIL2, FMT12, LIST9)                                                  ;
        IF Z[5]                                                     THEN
            WRITE (FIL4, FMT13, LIST10)                                             ;
        FOR J ← 0 STEP 1 UNTIL M-1 DO                                            BEGIN
            PHI ← ATAN(A1[J,3],A1[J,4])                                             ;
            IF PHI < 0                                              THEN
                PHI ← PHI + 6.28318534                                              ;
            POL ← 2×SQRT(A1[J,3]*2+A1[J,4]*2)/(CI×(1-RP2)×(1+RR2-2×RR×
                          COSDLT))                                                  ;
            V ← (A1[J,1]-CI×(1+RP2)×(1-RR2)×POL×SIN(PHI))/(2×CI×RR×
                          (1-RP2)×SIN(DELTA))                                       ;
        PHI ← 0.5×PHI                                                               ;
            WRITE (FIL2, FMT14, LIST11)                                          END  ;
L2:END                                                                              ;
        IF LAMBDA[L] < LAMBDA1                                      THEN
            Q ← 1                                                                   ;
                                                                                 END  ;
END                                                                                 ;
        IF Z[5]                                                     THEN         BEGIN
            REWIND (FIL4)                                                           ;
            IF Z[6]                                                 THEN  BEGIN
                WRITE (FIL2[PAGE])                                                  ;
                DATE (FIL2)                                                         ;
                DAYTIM (FIL2)                                                       ;
                WRITE (FIL2[DBL], FMT3)                                   END       ;
BEGIN LABEL L1,L2                                                                   ;
        FILE FIL6 0 (3,10)                                                          ;
        ARRAY A[0:9]                                                                ;
        DATE (FIL6)                                                                 ;
        DAYTIM (FIL6)                                                               ;
```

```
        WRITE (FIL6, FMT3)                                              ;
L1:     READ (FIL4, 10, A[*])[L2]                                       ;
        WRITE (FIL6, 10, A[*])                                          ;
        IF Z[6]                                   THEN
             WRITE (FIL2, 10, A[*])                                     ;
        GO TO L1                                                        ;
L2:     IF Z[6]                                   THEN
             WRITE (FIL2[PAGE])                                         ;
        CLOSE (FIL4, PURGE)                                             ;
END                                                                     ;
                                                          END           ;
L1:END                                                                  ;
        RNTIM2 ← TIME(2)/60                                             ;
        WRITE (FIL2, FMT1, RNTIM2)                                      ;
        RNTIM3 ←TIME(3)/60                                              ;
        WRITE (FIL2, FMT2, RNTIM3)                                      ;
END .
```

```
COMMENT -- FM DATA CONVERTER PROGRAM                                        ;
BEGIN INTEGER I,N,N1,N2,K1,K2,P,P1,TP,M,IFIL, IFL1,IF1,LBL,J1,J2,K3,K4,
IPAR                                                                        ;
      REAL RNTIM, RNTIM1, TM1, TM2, TM3, TM4                                ;
      ARRAY CT1, CT2[0:6], TIM[1:2,0:3,0:350], VAL[0:8]                     ;
      INTEGER ARRAY IFL[0:6]                                                ;
      SAVE ARRAY A,B[0:275]                                                 ;
      ALPHA ARRAY DT[0:1022]                                                ;
      BOOLEAN Z                                                             ;
      LABEL LFIL,LEND,L1,L1A,L1B,L2,L2B,L3,L4,LP1,LP2,LP3,LP4,LP5,LP6,
            LA, LP1A, LP3A, LP5A, LP2A, LP4A, LP6A, L1C, L1D, L5            ;
      LABEL L8,L9,L10,L11                                                   ;
      SAVE FILE IN FFMD1 2 (1,250), FFMD2 2 (1,250), FFMD3 2 (1,250),
                   FFMD4 2 (1,250), FFMD5 2 (1,250), FFMD6 2 (1,250)        ;
      FILE OUT ZZZZZ01 2 (1,1023, SAVE 100),
               ZZZZZ02 2 (1,1010, SAVE 30),
               ZZZZZ03 2 (1,1010, SAVE 30)                                  ;
      FILE IN FIL7 (1,10)                                                   ;
      FILE OUT FIL2 6 (2,15)                                                ;
      FILE OUT FILP1 2 (1,10, SAVE 1)                                       ;
      SWITCH FILE SWI1 := FFMD1, FFMD3, FFMD5                               ;
      SWITCH FILE SWI2 := FFMD2, FFMD4, FFMD6                               ;
      SWITCH FILE SWO1 := ZZZZZ01,ZZZZZ02,ZZZZZ03,ZZZZZ01,ZZZZZ01,
                          ZZZZZ01                                           ;
STREAM PROCEDURE STRM1(A,B,I,J,K);VALUE I,J,K; BEGIN SI:=A;DI:=B            ;
SI:=SI+2;DI:=DI+4;DS:=4 CHR;DI:=DI+5;DS:=3 CHR;SI:=SI+3                     ;
I(J(DI:=DI+2;DS:=6 CHR));K(DI:=DI+2;DS:=6 CHR)                END           ;
STREAM PROCEDURE STRM2(A,B,I,J,K);VALUE I,J,K; BEGIN SI:=A;DI:=B            ;
                          DI:=DI+5;DS:=3 CHR;SI:=SI+3                       ;
I(J(DI:=DI+2;DS:=6 CHR));K(DI:=DI+2;DS:=6 CHR)                END           ;
PROCEDURE DATE(FILE1)  ;FILE FILE1  ;BEGIN ALPHA D;INTEGER I,DY,YR          ;
```

```
INTEGER ARRAY MO[1:12];FORMAT OUT F1("RUN DATE ", I2,"/",I2,"/",I2/)    ;
FILL MO[*] WITH 31,28,31,30,31,30,31,31,30,31,30,31; D:=TIME(0)          ;
YR:=10×D.[18:6]+D.[24:6];DY:=100×D.[30:6]+10×D.[36:6]+D.[42:6]-1          ;
I:=0;FOR I:=I+1 WHILE DY>0 DO BEGIN DY:=DY-MO[I];IF YR MOD 4=0 THEN
IF I=2 THEN DY:=DY-1 END;I:=I-1;DY:=DY+MO[I];WRITE(FILE1,F1,I,DY,YR)END;
      INTEGER PROCEDURE WORD(F1, LBL)  ; FILE F1 ; INTEGER LBL            ;
BEGIN LABEL L1,L2,L3  ;
      INTEGER I     ; ARRAY A[0:2]  ; STREAM PROCEDURE S1(A,B); BEGIN
SI:=A;DI:=B;SI:=SI-8;DS:=8 CHR END; READ(F1[NO],1,A[*])[L1:L2]           ;
      S1(F1(0),I) ; LBL := 0 ; WORD := I  ; GO TO L3  ;
      L1: LBL := 1 ; GO TO L3 ; L2: LBL := 2  ; L3:                 END  ;
PROCEDURE OUT2(A,N,F1); VALUE N; INTEGER N; FILE F1; ALPHA ARRAY A[0]    ;
BEGIN INTEGER I,J,TM,T1,T2,T3;INTEGER ARRAY B[0:20];FORMAT OUT FMT1(I2,"
 HOURS",I3," MINUTES",I3," SECONDS",X10,"TIME ",I6,X44,"BLOCK NUMBER ",I
3,"-",I4),FMT2(4(I2,X2,I3,".",I3,X2,I4,".0",X7))                         ;
      J := A[0].[12:6]                                                    ;
FOR I:=1,2 DO BEGIN TM:=A[I].[30:17];T1:=TM DIV 3600;T2:=(TM-3600×T1)DIV
 60;T3:=TM-3600×T1-60×T2;WRITE(F1,FMT1,T1,T2,T3,TM,J,A[0].[18:30])END   ;
FOR I:=3STEP 4UNTIL N-3 DO BEGIN FOR J:=0,1,2,3 DO BEGIN IF I+J>N THEN A
[I+J]:=0;B[4×J]:=A[I+J].[43:5]                                            ;
         B[4×J+1]:=A[I+J].[25:8 ]                                         ;
         B[4×J+2]:=A[I+J].[33:10]                                         ;
         B[4×J+3]:=A[I+J].[14:11]                                   END  ;
         WRITE(F1,FMT2,FOR J:=0 STEP 1 UNTIL 15 DO B[J]) END END          ;
      FORMAT OUT FMTA("ACCUMULATED RUN TIME ", F8.2),
                 FMTB(X90, "PROJECT CODE ", I8),
                 FMTC(X57,"WORD COUNT ", I5),
                 FMTD("PARITY ERROR IN NEXT BLOCK AFTER ", I3,"-",I4,
                      "; TIMES: ", I5,", ",I5),
                 FP1("XXX PARITY ERROR, INPUT TAPE 1, FILE # ", I3),
                 FP2("XXX PARITY ERROR, INPUT TAPE 2, FILE # ", I3),
                 FP3("XXX PARITY ERROR, INPUT TAPE 1, STEP 2, FILE#",I3)
                ,FP4("XXX PARITY ERROR, INPUT TAPE 2, STEP 2, FILE#",I3)
                ,FP5("XXX PARITY ERROR, OUTPUT TAPE, STEP 1, FILE#",I3)
                ,FP6("XXX PARITY ERROR, OUTPUT TAPE, STEP 2, FILE#",I3);
PROCEDURE CALC1(N)                                                        ;
```

```
       VALUE N                                                               ;
       INTEGER N                                                             ;
BEGIN  INTEGER I,I1,I2,J,K                                                   ;
       REAL TM, T                                                            ;
OWN    BOOLEAN Z                                                             ;
       LABEL L1,L2                                                           ;
       OWN ARRAY B[0:1,0:10]                                                 ;
       FORMAT OUT FMTP ("01", X2, I2, X2, I3, X2, F9.3, " GRATING",X50),
                  FMTR ("02", X2, I2, X2, I3, X2, F9.3, " CALIBRATION",
                                                 X46)                        ;
       TM ← A[I2].[30:17] - A[2].[23:8]                                      ;
       FOR I := 4 STEP 4 UNTIL N-1 DO                                   BEGIN
           T ← A[I].[12:11]                                                  ;
           J ← 8                                                             ;
           DO J ← J - 1 UNTIL T ≥ VAL[J]                                     ;
           FOR I1 := 0,1 DO
               FOR K := 1 STEP 1 UNTIL 9 DO
                   B[I1,K-1] := B[I1,K]                                      ;
           B[0,9] ← J                                                        ;
           B[1,9] ← TM + A[I].[23:8] + A[I].[31:10]/1000                     ;
           FOR J := 1,3,5 DO                                            BEGIN
               FOR I1 := 0 STEP 1 UNTIL 4 DO
                   IF B[0,I1] ≠ J                           THEN
                        GO TO L1                                             ;
               FOR I1 := 5 STEP 1 UNTIL 9 DO
                   IF B[0,I1] ≠ J-1                         THEN
                        GO TO L1                                             ;
           CT1[IFIL] := CT1[IFIL] + 1                                        ;
           TIM[1,IFIL,CT1[IFIL]] := B[1,5]                                   ;
       WRITE (FILP1, FMTP, IFIL, CT1[IFIL], TIM[1,IFIL,CT1[IFIL]])           ;
           Z := FALSE                                                        ;
L1:                                                                     END  ;
       IF NOT Z                                             THEN        BEGIN
           FOR I1 := 0 STEP 1 UNTIL 3 DO
               IF B[0,I1] ≥ 4                               THEN
                   GO TO L2                                                  ;
```

179

```
          FOR I1 := 6 STEP 1 UNTIL 9 DO
               IF (B[0,I1] < 4) OR (B[0,I1] > 5)     THEN
                    GO TO L2                                              ;
          Z := TRUE                                                       ;
          CT2[IFIL] := CT2[IFIL] + 1                                      ;
          TIM[2,IFIL,CT2[IFIL]] := 3.0 + B[1,5]                           ;
     WRITE (FILP1, FMTR, IFIL, CT2[IFIL], TIM[2,IFIL,CT2[IFIL]]) END      ;
L2:                                                             END
     END                                                                  ;
     RNTIM := TIME(2)                                                     ;
     DATE(FIL2)                                                           ;
     IPAR := 0                                                            ;
     READ (FIL7, /, FOR I:=0 STEP 1 UNTIL 7 DO VAL[I])                    ;
     READ (FIL7, /, Z, P, P1, TP, M)                                      ;
     READ (FIL7, /, FOR I:=0 STEP 1 UNTIL TP-1 DO IFL[I])                 ;
     IF1 := 0                                                             ;
     READ (FIL7, /, I)[L1B]                                               ;
     IF1 := 3                                                             ;
L1B: CLOSE (FIL7, RELEASE)                                                ;
LP1A:
     DT[0] := 0                                                           ;
LFIL: N1 := WORD (SWI1[IFIL], LBL)                                        ;
     IF LBL=1 THEN GO TO L8  ELSE IF LBL=2 THEN GO TO LP1                 ;
     DT[0].[12:6] ← IFL1 + 1                                              ;
     N1 := 4×(N1 DIV 3) + N1 MOD 3                                        ;
     K1 := (N1-2) DIV 63                                                  ;
     K2 := (N1-2) MOD 63                                                  ;
     STRM1 (SWI1[IFIL](0), A[0], K1, 63, K2)                              ;
     CALC1(N1)                                                            ;
     RELEASE (SWI1[IFIL])                                                 ;
LA:  N2 := WORD (SWI2[IFIL], LBL)                                         ;
     IF LBL=1 THEN GO TO L9  ELSE IF LBL=2 THEN GO TO LP2                 ;
     N2 := 4×(N2 DIV 3) + N2 MOD 3                                        ;
     K1 := (N2-2) DIV 63                                                  ;
     K2 := (N2-2) MOD 63                                                  ;
     STRM1 (SWI2[IFIL](0), B[0], K1, 63, K2)                              ;
```

```
          RELEASE (SWI2[IFIL])                                              ;
          K3 := A[1]                                                        ;
          K4 := B[1]                                                        ;
          DT[1003] := A[0]                                                  ;
          DT[1004] := B[0]                                                  ;
          J1 := J2 := 2                                                     ;
LP3A:
L1:       N ← IF DT[0].[18:30] = 0 THEN 5 ELSE 3                            ;
          FOR I := 0 STEP 2 UNTIL 498 DO                                BEGIN
L1C:           IF I+J1+2 > N1                               THEN  BEGIN
                    J1 := 1-I                                               ;
                    N1 := WORD (SWI1[IFIL], LBL)                            ;
               IF LBL=1 THEN GO TO L10 ELSE IF LBL=2 THEN GO TO LP3         ;
                    N1 := 4×(N1 DIV 3) + N1 MOD 3                           ;
                    K1 := (N1-1) DIV 63                                     ;
                    K2 := (N1-1) MOD 63                                     ;
                    STRM2 (SWI1[IFIL](0), A[0], K1, 63, K2)                 ;
                    TM3 ← A[0].[30:17] - A[1].[23:8]                        ;
                    CALC1(N1)                                               ;
                    RELEASE (SWI1[IFIL])                          END       ;
L1A:           IF I+J2+2 > N2                               THEN  BEGIN
                    J2 := 1-I                                               ;
                    N2 := WORD (SWI2[IFIL], LBL)                            ;
               IF LBL=1 THEN GO TO L11 ELSE IF LBL=2 THEN GO TO LP4         ;
                    N2 := 4×(N2 DIV 3) + N2 MOD 3                           ;
                    K1 := (N2-1) DIV 63                                     ;
                    K2 := (N2-1) MOD 63                                     ;
                    STRM2 (SWI2[IFIL](0), B[0], K1, 63, K2)                 ;
                    TM4 ← B[0].[30:17] - B[1].[23:8]                        ;
                    RELEASE (SWI2[IFIL])                          END       ;
               IF A[I+J1] =0                                THEN  BEGIN
                    TM1 ← TM1 + 256.0                                       ;
                    J1 := J1 + 1                                            ;
                    GO TO L1C                                     END       ;
               IF B[I+J2] = 0                               THEN  BEGIN
                    TM2 ← TM2 + 256.0                                       ;
```

```
            J2 := J2 + 1                                                     ;
            GO TO L1A                                          END           ;
        IF I = 0                                          THEN
            IF DT[0].[18:30] = 0                     THEN  BEGIN
                K3 ← A[1].[30:17]-A[2].[23:8]                                ;
                K4 ← B[1].[30:17]-B[2].[23:8]                      END
                                                          ELSE  BEGIN
                K3 ← A[0].[30:17]-A[1].[23:8]                                ;
                K4 ← B[0].[30:17]-B[1].[23:8]                      END       ;
        DT[2×I+3].[14:29] := A[I+J1   ].[12:29]                              ;
        DT[2×I+3].[43:5]  := A[I+J1   ].[43:5]                               ;
        DT[2×I+4].[14:29] := A[I+J1+1].[12:29]                               ;
        DT[2×I+4].[43:5]  := A[I+J1+1].[43:5]                                ;
        DT[2×I+5].[14:29] := B[I+J2   ].[12:29]                              ;
        DT[2×I+5].[43:5]  := 3                                               ;
        DT[2×I+6].[14:29] := B[I+J2+1].[12:29]                               ;
        DT[2×I+6].[43:5]  := 4                                               ;
    TM1 ← DT[2×I+3].[25:8] + DT[2×I+3].[33:10]/1000 + TM3                    ;
    TM2 ← DT[2×I+5].[25:8] + DT[2×I+5].[33:10]/1000 + TM4                    ;
    IF TM1 ≠ TM2                                          THEN       BEGIN
        IF ABS(TM1-TM2) = 0.001                           THEN
            GO TO L5                                                         ;
        IF ABS(TM1-TM2) ≤ 0.700                           THEN  BEGIN
            IF TM1 > TM2                                  THEN  BEGIN
                J2 ← J2 + 2                                                  ;
                GO TO L1A                                          END
                                                          ELSE  BEGIN
                J1 ← J1 + 2                                                  ;
                GO TO L1C                                          END       ;
                                                                   END       ;
        DT[1].[30:17] ← K3 + DT[3].[25:8]                                    ;
        DT[2].[30:17] ← K4 + DT[5].[25:8]                                    ;
        WRITE (FIL2[NO], FMTC, N)                                            ;
        WRITE (SW01[IFIL+IF1], N, DT[*])                                     ;
        OUT2 (DT, N+3, FIL2)                                                 ;
        IF TM1 < TM2                                      THEN  BEGIN
```

```
                    N1 ← 0                                                            ;
                    J1 ← J2 ← 1                                                       ;
                    GO TO L1                                           END            ;
                    N2 ← 0                                                            ;
               J1 ← J2 ← 1                                                            ;
               GO TO L1                                                     END       ;
               IF DT[2×I+3].[33:10] MOD 500=0 AND I≠498    THEN    BEGIN
                    DT[0].[18:30] ← DT[0].[18:30] + 1                                 ;
                    IF DT[0].[18:30] = 1                   THEN
                         OUT2 (DT, N-3, FIL2)                                         ;
                    WRITE (SWO1[IFIL+IF1], N, DT[*])                                  ;
                    J1 ← I + J1 + 2                                                   ;
                    J2 ← I + J2 +2                                                    ;
                    GO TO L1                                           END            ;
               N ← N +4                                                               ;
L5:                                                                         END       ;
          DT[0].[18:30] ← DT[0].[18:30] + 1                                           ;
          DT[1].[30:17] ← K3 + DT[3].[25:8]                                           ;
          DT[2].[30:17] ← K4 + DT[5].[25:8]                                           ;
          IF DT[0].[18:30] = 1                                     THEN
               OUT2 (DT, N-3, FIL2)                                ELSE
               FOR I ← 0 STEP 1 UNTIL P1-1 DO
                    IF DT[0].[18:30] MOD P = I                     THEN
                         OUT2 (DT, N-1, FIL2)                                         ;
          WRITE (SWO1[IFIL+IF1], N, DT[*])                                            ;
          J1 := 500 + J1                                                              ;
          J2 := 500 + J2                                                              ;
          IF Z OR (DT[0].[18:30] ≤ M)                              THEN
               GO TO L1                                                               ;
L2:       IFL1 := IFL1 + 1                                                            ;
          OUT2 (DT, 1002, FIL2)                                                       ;
          DT[0] ← 0                                                                   ;
          IF IFL1 < IFL[IFIL]                                      THEN        BEGIN
               WRITE (FIL2[PAGE])                                                     ;
               GO TO LFIL                                                   END       ;
          IFL1 ← 0                                                                    ;
```

```
        LOCK (SWI1[IFIL], RELEASE)                                    ;
        LOCK (SWI2[IFIL], RELEASE)                                    ;
        IF IF1 = 0                                        THEN
            CLOSE (SWO1[IFIL+IF1], *)                     ELSE
            REWIND (SWO1[IFIL+IF1])                                   ;
        WRITE (FIL2[PAGE])                                            ;
        IFIL := IFIL + 1                                              ;
        IF IFIL < TP                                      THEN
            GO TO LFIL                                                ;
        RNTIM1 := (TIME(2) - RNTIM)/60                                ;
        WRITE (FIL2, FMTA, RNTIM1)                                    ;
        WRITE (FIL2[PAGE])                                            ;
        REWIND (FILP1)                                                ;
        REWIND (SWO1[IFIL+IF1-1])                                     ;
        IFIL := 0                                                     ;
LP5A:
L2B:    N := WORD(SWO1[IFIL], LBL)                                    ;
        IF LBL = 1 THEN GO TO L4    ELSE IF LBL = 2 THEN GO TO LP4    ;
        READ (SWO1[IFIL], N, DT[*])                                   ;
        WRITE (FIL2, FMTB, FOR I:=2,1DO DT[N-I])                      ;
        WRITE (FIL2[NO], FMTC, N)                                     ;
        OUT2 (DT, N-3, FIL2)                                          ;
        SPACE (SWO1[IFIL], P-2)[L4]                                   ;
L3:     FOR I := 0 STEP 1 UNTIL P1-1 DO                           BEGIN
LP6A:
            J1 ← DT[0].[12:6]                                         ;
            N := WORD (SWO1[IFIL], LBL)                               ;
            IF LBL = 1 THEN GO TO L4 ELSE IF LBL = 2 THEN GO TO LP6   ;
            READ (SWO1[IFIL], N, DT[*])                               ;
            IF DT[0].[12:6] ≠ J1                          THEN  BEGIN
                SPACE (SWO1[IFIL], -DT[0].[18:30])                    ;
                GO TO L2B                                       END   ;
            IF (DT[0].[18:30] MOD P) ≠ I                  THEN  BEGIN
                SPACE(SWO1[IFIL],P+I-(DT[0].[18:30] MOD P))[L4:LP6]   ;
                OUT2 (DT, N-1, FIL2)                                  ;
                GO TO LP6A                                      END   ;
```

```
          WRITE (FIL2[N0], FMTC, N)                                   ;
          OUT2 (DT, N-1, FIL2)                                   END  ;
     SPACE (SW01[IFIL], P-P1)[L4]                                     ;
     GO TO L3                                                         ;
L4:  RNTIM1 := (TIME(2) - RNTIM)/60                                   ;
     WRITE (FIL2[PAGE], FMTA, RNTIM1)                                 ;
     IFIL := IFIL + 1                                                 ;
     IF IFJ = 0                                          THEN
     IF IFIL < TP                                        THEN
          GO TO L2B                                                   ;
     LOCK (SW01[IFIL], RELEASE)                                       ;
     GO TO LEND                                                       ;
L9:  SPACE (SWI1[IFIL], 1)[L2:L9]                                     ;
L8:  SPACE (SWI2[IFIL], 1)[L2:L8]                                     ;
L10: SPACE (SWI2[IFIL], 1)[L2:L10]                                    ;
L11: SPACE (SWI1[IFIL], 1)[L2:L11]                                    ;
LP1: WRITE (FIL2[DBL], FP1, IFIL)                                     ;
     RELEASE (SWI1[IFIL])                                             ;
     N1 := N2 := 0                                                    ;
     WRITE (FILP1, FMTD, DT[0].[12:6], DT[0].[18:30],DT[1].[30:17],
                              DT[2].[30:17])                          ;
     IPAR := IPAR + 1                                                 ;
     IF IPAR > 10 THEN GO TO LEND                                     ;
     GO TO LP1A                                                       ;
LP2: WRITE (FIL2[DBL], FP2, IFIL)                                     ;
     RELEASE (SWI2[IFIL])                                             ;
     N1 := N2 := 0                                                    ;
     WRITE (FILP1, FMTD, DT[0].[12:6], DT[0].[18:30],DT[1].[30:17],
                              DT[2].[30:17])                          ;
     IPAR := IPAR + 1                                                 ;
     IF IPAR > 10 THEN GO TO LEND                                     ;
     GO TO LP1A                                                       ;
LP3: WRITE (FIL2[DBL], FP3, IFIL)                                     ;
     RELEASE (SWI1[IFIL])                                             ;
     N1 := N2 := 0                                                    ;
     J1 := J2 := 1                                                    ;
```

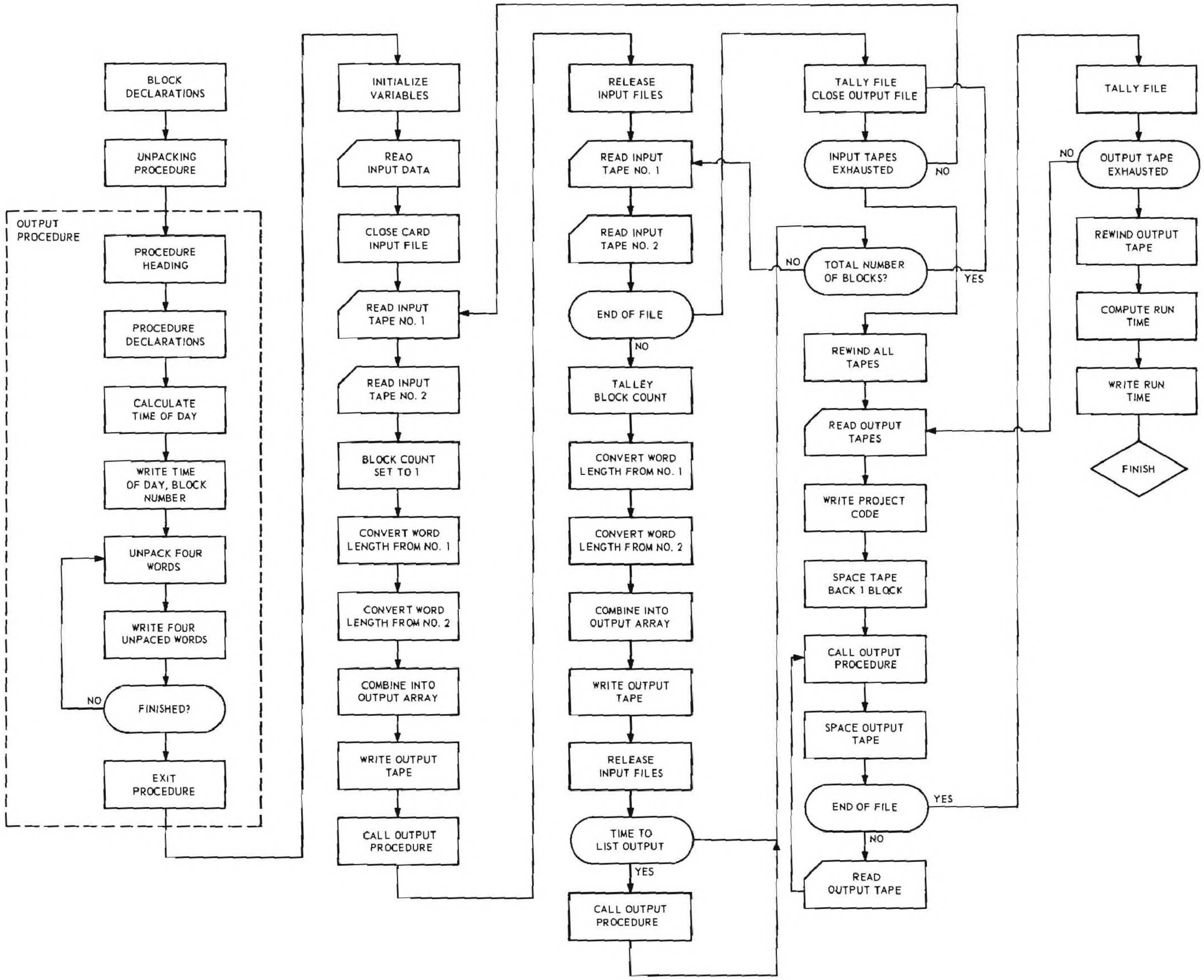
```
       WRITE (FILP1, FMTD, DT[0].[12:6], DT[0].[18:30],DT[1].[30:17],
                               DT[2].[30:17])                          ;
       IPAR := IPAR + 1                                                ;
       IF IPAR > 10 THEN GO TO LEND                                    ;
       GO TO LP3A                                                      ;
LP4:   WRITE (FIL2[DBL], FP4, IFIL)                                    ;
       RELEASE (SWI2[IFIL])                                            ;
       N1 := N2 := 0                                                   ;
       J1 := J2 := 1                                                   ;
       WRITE (FILP1, FMTD, DT[0].[12:6], DT[0].[18:30],DT[1].[30:17],
                               DT[2].[30:17])                          ;
       IPAR := IPAR + 1                                                ;
       IF IPAR > 10 THEN GO TO LEND                                    ;
       GO TO LP3A                                                      ;
LP5:   WRITE (FIL2[DBL], FP5, IFIL)                                    ;
       RELEASE (SWO1[IFIL])                                            ;
       IPAR := IPAR + 1                                                ;
       IF IPAR > 10 THEN GO TO LEND                                    ;
       GO TO LP5A                                                      ;
LP6:   WRITE (FIL2[DBL], FP6, IFIL)                                    ;
       RELEASE (SWO1[IFIL])                                            ;
       IPAR := IPAR + 1                                                ;
       IF IPAR > 10 THEN GO TO LEND                                    ;
       GO TO LP6A                                                      ;
LEND:
BEGIN  LABEL L1,L2                                                     ;
       FILE FILPN 0 (1,10)                                             ;
       ALPHA ARRAY A[0:9]                                              ;
       REWIND (FILP1)                                                  ;
       WRITE (FIL2[PAGE])                                              ;
L1:    READ (FILP1, 10, A[*])[L2]                                      ;
       WRITE (FILPN, 10, A[*])                                         ;
       WRITE (FIL2,  10, A[*])                                         ;
       GO TO L1                                                        ;
L2:    CLOSE (FILP1, PURGE)                                            ;
END                                                                    ;
END  .
```

```
COMMENT -- DUMP PROGRAM                                                    ;
BEGIN INTEGER I, ITM, N                                                    ;
      ARRAY A[0:600], STRT, STPTM[0:25]                                    ;
      LABEL L1, L2, L3                                                     ;
      FILE IN FIL1 (1,10), FLDT2 2 "MULF1" "FLDT3" (1,600)                 ;
      FILE OUT FIL2 1 (1,15)                                               ;
STREAM PROCEDURE WORD(A,B); BEGIN SI←A;DI←B;SI←SI-8;DS←8 CHR END           ;
PROCEDURE OUT1(A,N,FILEID);VALUE N; INTEGER N;FILE FILEID; ALPHA      ARRAY
      A[0]                                                                 ;
BEGIN INTEGER I,J, TM, THR, TMIN, TSEC ; ARRAY B[1:20]                     ;
FORMAT OUT FMT1(I2, " HOURS", I3, " MINUTES", I3, " SECONDS", X10, I10,
                                  X45, "BLOCK NUMBER ", I8),
           FMT2(4(I2  , X1, F8.3, X1, F7.1, X1, F5.0, X2))                 ;
      FOR I ← 1,2 DO                                                  BEGIN
           TM ← A[I].[30:17]                                               ;
           THR ← TM DIV 3600                                               ;
           TMIN ← (TM - 3600×THR) DIV 60                                   ;
           TSEC ← TM - 3600×THR - 60×TMIN                                  ;
           WRITE (FILEID, FMT1, THR, TMIN, TSEC, TM, A[0])            END  ;
      FOR I ← 3 STEP 4 UNTIL N    DO                                  BEGIN
           FOR J ← 0 STEP 1 UNTIL 3 DO                          BEGIN
                IF (I+J) > N                                THEN
                     A[I+J] := 0                                           ;
                B[4×J+1] ← A[I+J].[43:5]×1.0                               ;
                B[4×J+2] ← A[I+J].[25:8] + A[I+J].[33:10]/1000             ;
                B[4×J+3] ← A[I+J].[14:11]×1.0                              ;
                B[4×J+4] ← A[I+J].[1:13]×1.0                    END        ;
           WRITE (FILEID,FMT2,FOR J←1 STEP 1 UNTIL 16 DO B[J])        END  ;
END OUT1                                                                   ;
      READ (FIL1, /, ITM)                                                  ;
      READ (FIL1,/,FOR I←0 STEP 1 UNTIL ITM-1 DO [STRT[I],STPTM[I]])       ;
```

```
      CLOSE (FIL1, RELEASE)                                              ;
      FOR I ← 0 STEP 1 UNTIL ITM-1 DO                               BEGIN
           SPACE (FLDT2, 1)                                              ;
L1:        READ (FLDT2[NO], 1, A[*])[L3]                                 ;
           WORD (FLDT2(0), N)                                            ;
           READ (FLDT2, N, A[*])[L3]                                     ;
           IF A[1].[30:17] < STRT[I]                     THEN
                GO TO L1                                                 ;
           SPACE (FLDT2, -1)                                             ;
L2:        READ (FLDT2[NO], 1, A[*])[L3]                                 ;
           WORD (FLDT2(0), N)                                            ;
           READ (FLDT2, N, A[*])[L3]                                     ;
           IF A[1].[30:17] > STPTM[I]                    THEN
                GO TO L3                                                 ;
           OUT1 (A, N-1, FIL2)                                           ;
           GO TO L2                                                      ;
L3:        REWIND (FLDT2)                                           END  ;
      LOCK (FLDT2, RELEASE)                                              ;
END .
```

```
COMMENT -- AVERAGING PROGRAM                                                      ;
BEGIN INTEGER I,J,K,L,I1,TM,THR,TMIN,TSEC1,N,IFIL,IFIL1                           ;
      REAL RNTIM, TSEC2                                                           ;
      ARRAY A[0:600], MIN, MAX, B[1:4]                                            ;
      LABEL L0, L1, L2, L3                                                        ;
      FILE OUT FIL2 1 (1,15)                                                      ;
      FILE IN FLDT1    "MULF1" "FLDT1" (1,1000),
              FLDT2    "MULF1" "FLDT2" (1,1000),
              FLDT3    "MULF1" "FLDT3" (1,1000),
              FLDT4    "MULF1" "FLDT4" (1,1000)                                   ;
      SWITCH FILE SWFIL ← FLDT2, FLDT3, FLDT1, FLDT4                              ;
      LIST LIST1(THR,TMIN,TSEC2,FOR J←1,2,3 DO [B[J],MIN[J],MAX[J]])              ;
      FORMAT OUT FMT1("VOLTAGE CALIBRATION OF",X80, I10/"SUBCARRIER ",
                      "OSCILLATORS"//X4,"TIME"X22,"22.0 KC",X23,
                      "30.0 KC",X23,"40.0"//),
                 FMT2(I2,":",I2,":",F6.3,X5, 3(3(F8.2, X2),X3)),
                 FMT3("RUN TIME: ", F8.2, " SECONDS")                             ;
      RNTIM ← TIME(2)                                                             ;
      N ← 511                                                                     ;
      IFIL  ← 0                                                                   ;
      IFIL1 ← 4                                                                   ;
      FOR I ←0 STEP 1 UNTIL 4 DO
      SPACE (SWFIL[IFIL], 50)                                                     ;
L0:   READ (SWFIL[IFIL], N+1, A[*])                                               ;
      WRITE (FIL2, FMT1, A[N])                                                    ;
L2:   FOR I ← 4 STEP 200 UNTIL N-1 DO                                        BEGIN
           FOR I1 ← 1,2,3 DO                                      BEGIN
                MIN[I1] ← 0                                                       ;
                MAX[I1]  ← 99999                                  END             ;
           L ← 50                                                                 ;
           FOR J ← 1,2,3 DO
```

```
                B[J] ← 0                                                                  ;
            FOR J ← 0 STEP 1 UNTIL 49 DO                              BEGIN
                K ← I + 4×J - 1                                                           ;
                IF K > N-1                             THEN  BEGIN
                    L ← J                                                                 ;
                    GO TO L1                                 END                          ;
                FOR I1 ← 1,2,3 DO                            BEGIN                        ;
                    IF A[K+I1].[14:11] > MIN[I1]  THEN
                          MIN[I1] ← A[K+I1].[14:11]                                       ;
                    IF A[K+I1].[14:11] < MAX[I1]  THEN
                          MAX[I1] ← A[K+I1].[14:11]                                       ;
                    B[I1] ← B[I1] + A[K+I1].[14:11]  END   END                            ;
L1:         FOR I1 ← 1,2,3 DO
                B[I1] ← B[I1]/L                                                           ;
            TM ← A[1].[30:17] - A[3].[25:8] + A[I].[25:8]                                 ;
            THR ← TM DIV 3600                                                             ;
            TMIN ← (TM - 3600×THR) DIV 60                                                 ;
            TSEC1 ← TM - 3600×THR - 60×TMIN                                               ;
            TSEC2 ← TSEC1 + A[I].[33:10]/1000                                             ;
            WRITE (FIL2, FMT2, LIST1)                                          END        ;
        READ (SWFIL[IFIL], N, A[*])[L3]                                                   ;
        GO TO L2                                                                          ;
L3:     IFIL ← IFIL + 1                                                                   ;
        REWIND (SWFIL[IFIL-1])                                                            ;
        WRITE (FIL2[PAGE])                                                                ;
        IF IFIL < IFIL1 THEN GO TO LO                                                     ;
        RNTIM ← (TIME(2) - RNTIM)/60                                                      ;
        WRITE (FIL2, FMT3, RNTIM)                                                         ;
END .
```



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This report documents the design, construction, and data reduction techniques of a balloon borne ultraviolet Ebert-Sekera spectrophotopolarimeter, whose purpose is to measure the natural sky backgrounds at altitudes greater than 100,000 feet. Considerable detail has been spent in describing the various mechanical, electrical and optical components of the system to serve as a guide for future improvements and alterations of the instrument. The data reduction section describes the various computer programs that have been necessary in order to reduce the large amount of data that is obtained. Intensity data at altitude has not been obtained as of yet, but the system has been shown to be capable of giving intensity and the Stokes parameters of the incident light.

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14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
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Sky Background Studies	5	1				
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